ธรณีวิทยาควอเทอร์นารีและอุทกธรณีวิทยา เขตอำเภอ คูเมือง จ.บุรีรัมย์

นาย ภูวดล วรรธนะชัยแสง

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QUATERNARY GEOLOGY AND HYDROGEOLOGY OF AMPHOE KHU MUANG, CHANGWAT BURI RAM

Mr. Bhuwadol Wanthanachaisaeng

for the Degree of Master of Science in Geology

Department of Geology Faculty of Science

Chulalongkorn University

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ภูวดล วรรธนะชัยแสง: ธรณีวิทยาควอเทอนารีและอุทกธรณีวิทยาเขตอำเภอคูเมือง จ.บุรีรัมย์ (QUATERNARY GEOLOGY AND HYDROGEOLOGY OF AMPHOE KHUMUANG, CHANGWAT BURI RAM) อ.ที่ปรึกษา: ผศ. ปองศักดิ์ พงษ์ประยูร, อ.ที่ปรึกษาร่วม : นายวิฑิต ศิริโภคากิจ 162 หน้า ISBN 974-13-1281-4

การศึกษาธรณีวิทยาควอเทอนารีและอุทกธรณีวิทยาในเขตอำเภอคูเมือง จังหวัดบุรีรัมย์ โดยใช้ข้อมูลเศษหิน ธรณีฟิสิกส์ และคุณภาพน้ำจากหลุมเจาะน้ำบาดาลในพื้นที่ที่ศึกษาเพื่ออธิบายธรณีวิทยาใต้พื้นผิว แบบจำลองน้ำบาดาลและสภาพแวดล้อมการสะสมตัวของตะกอน

จากการศึกษาธรณีวิทยาควอเทอนารีสามารถแบ่งหมวดของตะกอนออกเป็น 2 หมวด โดยใช้ความแตกต่างของลักษณะตะกอนและธรณีฟิสิกส์ หมวดตะกอน A มีลักษณะเป็นตะกอนดินเหนียวสีแดง ซึ่งถือเป็นตะกอนพื้นฐานของพื้นที่ที่ศึกษา หมวดตะกอน B มีลักษณะเป็นชั้นทรายสลับกับชั้นดินเหนียว ซึ่งสามารถแบ่งออกเป็นชุดตะกอนได้ 5 ชุด คือ BM, BN, BO, BP, และBQ โดยใช้ความแตกต่างของสีและลักษณะตะกอน ชุดตะกอนเหล่านี้เกิดจากการสะสมตัวของของตะกอนธารน้ำพาและทะเลสาบ ลักษณะเด่นของชุดตะกอน BM, BO และ BQ คือ การสะสมตัวมีการคัดขนาดจากขนาดใหญ่ไปสู่ขนาดเล็ก ลักษณะทางอุทกธรณีวิทยาสามารถแบ่งชุดตะกอน BM และ BO เป็นชั้นหินอุ้มน้ำและหมวดตะกอน A ชุดตะกอน BN และ BP เป็นชั้นหินซับน้ำ ชั้นหินอุ้มน้ำทั้ง 2 ชั้นถูกปิดกั้นด้วยชุดตะกอน BP ทำให้เกิดเป็นชั้นน้ำมีแรงดัน ซึ่งระดับแรงดันน้ำอยู่สูงจากระดับน้ำทะเลประมาณ 150 เมตรลักษณะดังกล่าวทำให้เกิดแอ่งน้ำบาดาลมีแรงดันในบริเวณทิศเหนือของพื้นที่ ซึ่งครอบคลุมพื้นที่เกือบทั้งหมดยกเว้นบริเวณทิศใต้ คุณภาพน้ำของชุดตะกอน BM มีลักษณะเป็นน้ำกร่อยในบริเวณทิศเหนือ ซึ่งเกิดจากการแพร่ของสารละลายจากแร่เกลือหินซึ่งแทรกตัวอยู่ในหมวดตะกอน A และแพร่เข้าสู่ชุดตะกอน BM

ภาควิชา..........ธรณีวิทยา..............	ลายมือชื่อนิสิต ....
สาขาวิชา ....ธรณีวิทยา.............	ลายมือชื่ออาจารย์ที่ปรึกษา ....
ปีการศึกษา ....2543.................	ลายมือชื่ออาจารย์ที่ปรึกษาร่วม ....

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KEY WORDS: QUATERNARY GEOLOGY / HYDROGEOLOGY / BURI RAM

BHUWADOL WANTHANACHAISAENG: QUATERNARY GEOLOGY AND HYDROGEOLOGY OF AMPHOE KHU MUANG, CHANGWAT BURI RAM. THESIS ADVISOR: ASSIST. PROF. PONGSAK PONGPRAYOON, THESIS CO-ADVISOR: Mr. WITHIT SIRIPHOCAGIT, 162 PP. ISBN 974-13-1281-4

This investigation of the Quaternary geology and hydrogeology purposes are to explain the subsurface geology, groundwater modeling, and the environment of deposition of Amphoe Khu Muang, Changwat Buri Ram. The data of cuttings, E-logs and groundwater quality data of the groundwater well, that distributed in the area, are used in the investigation.

The Quaternary geology of Amphoe Khu Muang, Changwat Buri Ram can be divided to 2 formation by the sedimentary and E-logs character. The formation A is red clay which is the basement of the investigated area. The other is formation B which is an alternation of sand and clay. It can be divided this formation into 5 members as BM, BN, BO, BP, and BQ by the differentiation of colors and sedimentary character. These members are fluvialtile lacustrine deposits. The typical character is the finning upward sequence in BM, BO, and BQ member. The hydrogeology can be classified the BM and BO member as aquifers. The formation A, BN, and BP members are aquitard. The both aquifers are confined by member BP. The piezometric level is about 150 meters above mean sea level. The artesian flowing well phenomena appeared sacredly throughout the investigate area especially in the northern part. For the southern part, no artesian flowing well phenomena found. In the lower aquifer of the northern artesian flowing well phenomena, the brackish water is detected. The brackish water is dispersed from the lens of rock salt in the formation A and transgresses to the member BM.

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Chapter I

Introduction

This report is the partial fulfillment of graduate course, Department of Geology, Chulalongkorn University by the title of "Quaternary Geology and Hydrogeology of Amphoe Khu Muang, Changwat Buri Ram". The purposes of this report are to study the Quaternary geology and hydrogeology, the extension of aquifers, and the model of groundwater system. The study area covers Amphoe Khu Muang, Changwat Buri Ram that is situated in northeast Thailand. The data used in this study are cuttings, E-logs, and water quality data from the groundwater wells that drilled by the Groundwater Division, Department of Mineral Resources (DMR.). The result of this study will be appiled in the groundwater project planning and developing in the area and adjacent zone.

1.1 General

The ¾ part of the world is covered by the water. Therefore it is considered to be one of the fundamental elements. It is really significant for all lives. Since it is, for instance, the dwell of life, a part in the mechanism of life, the controller of the world temperature and etc. For human, water is particularly important because it's need as a factor of surviving and also the factor of almost all activities.

There are many sources of water that have been utilized today. Considering the hydrologic cycle (figure 1.1), many interesting water circulate in the world as: precipitation, surface water, and groundwater; for instance. The total reservoir volume of hydrologic cycle is approximately 1.46×10^9 km^3, the precipitation on land volume is about 107×10^3 km^3, the surface volume is around 360×10^3 km^3, and the groundwater volume is about $15{,}300 \times 10^3$ km^3 (NRC, 1986). In this numerical with the figure mentioned above, the supply of groundwater on the continental is very appealing because there is large quantity of it and it loses only a little to the environment.

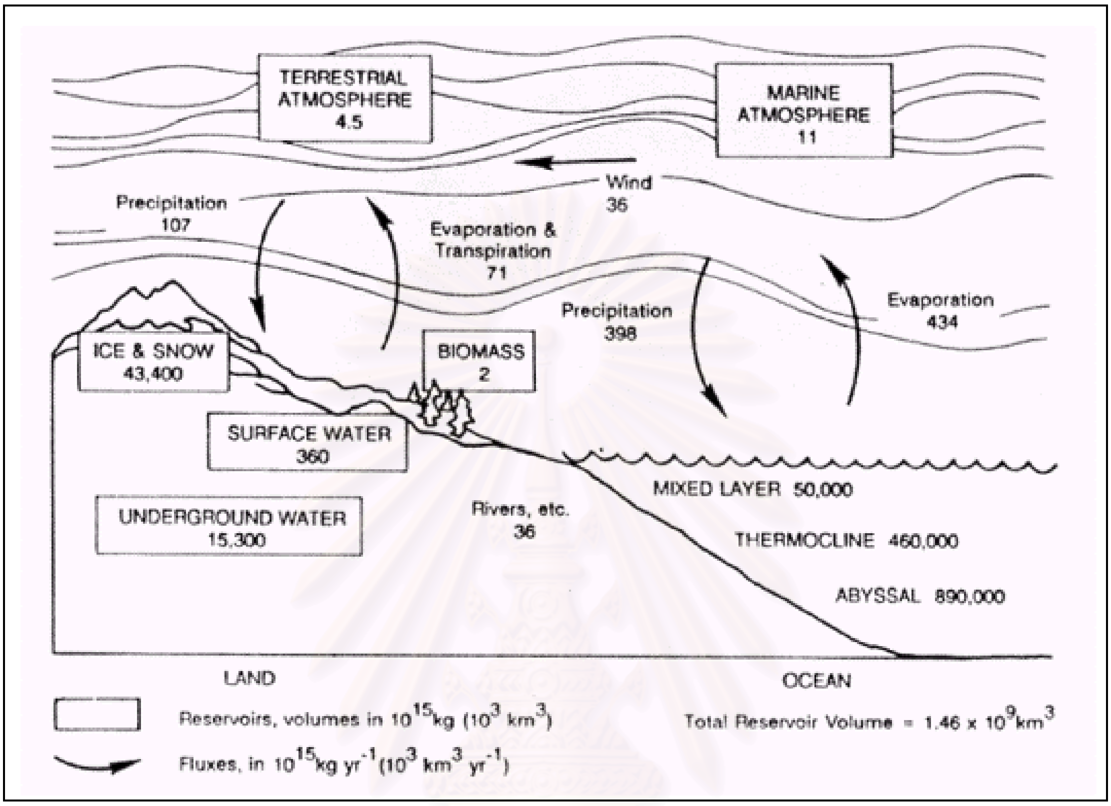

Figure 1.1 The climatic hydrologic cycle at global scale (from NRC, 1986).

Nowadays, the groundwater exploration has been accelerated the development because it is a better method to solve the drought problem. The groundwater is extensive, while the quantity and quality depend on the geology and morphology of groundwater reservoirs. The reservoir character is depended on the porosity, permeability, transmissivity, strorativity, and etc. The results of these characters are taken in to account for the different degree of magnitude of supply water.

In Thailand, there are several organizations that respond to solve problem of drought such as the Groundwater Division, DMR., The Public Works Department, the Royal Irrigation Department, the Department of Health, the Office of Accelerated

Rural Development, and the Ministry of Interior. The government official units are assigned to explore and develop the distribution system of groundwater usage.

The groundwater well developments, a method to clarify the drought problem, are constructed by drilling into the subsurface where it has the potential of groundwater. In most area, the groundwater wells are not supervised by the professional geologist to locate, drill, and test because the cost of systematic scientific studies commonly exceeds the expected benefits. But in the regional scale, the study of the geological information will be a positive guidance for the location of wells to avoid the expense of dry or unsuccessful wells. This is also the reason that used to make a decision to study of this area.

1.2 Purpose and scope

In the title of this thesis, the purposes of this study are:

1. Study the subsurface geology from cuttings of the groundwater wells.
2. Study the quality variation of groundwater in aquifers.
3. Study the extension of the aquifer.
4. Interpret the environment of deposition.

The data that used are based on the data from the developing of groundwater in Tung Kula Rong Hai Project by Groundwater Division, DMR. The data uses are cuttings, E-logs and water quality data of the well at least 70 wells that distributed around the area.

1.3 Description of study area

1.3.1 Location and accessibility

The study area is situated in the Northeast Thailand (figure 1.2). The area is a part of southern Khorat Plateau. It is located at Amphoe Khu Muang, Changwat Buri Ram limited by latitudes $15^{o}15'$ N and $15^{o}25'$ N and longitudes $103^{o}00'$ E and $103^{o}05'$ E. The area appears in the topographic map scale 1:250,000, sheet ND 48-1, series L7017, Changwat Chaiyaphum (figure 1.3) and topographic map scale 1: 50,000, sheet No. 5639 IV Amphoe Khu Muang (figure 1.4). The boundary of area associated with Amphoe Phutthaisong, Changwat Buri Ram on the north, Amphoe Chum Phuang, Changwat Nakorn Ratchasima on the west and Amphoe Muang and Amphoe Lam Plai Mat on the south.

The area is approximately 410 kilometers from Bangkok to Buri Ram (Tourism Authority of Thailand). This area can be accessed by highway No. 1 from Bangkok to Nakorn Ratchasima. After that, using the highway No. 206 from Nakorn Ratchasima to Amphoe Phimai. Next, by the highway No. 2175 from Amphoe Phimai to Amphoe Chum Phuang and lastly by the highway No. 2226 from Amphoe Chum Phuang to Amphoe Khu Muang. All of these highways are asphaltic road. The railway does not passed through the area.

1.4 Topography

The topography of Amphoe Khu Muang, Changwat Buri Ram is consisted of flood plain in the northern and central part, the terrace and rolling hill is extended in the southern part of the area (figure 1.5). It can be divided the topographic landforms into 4 types as:

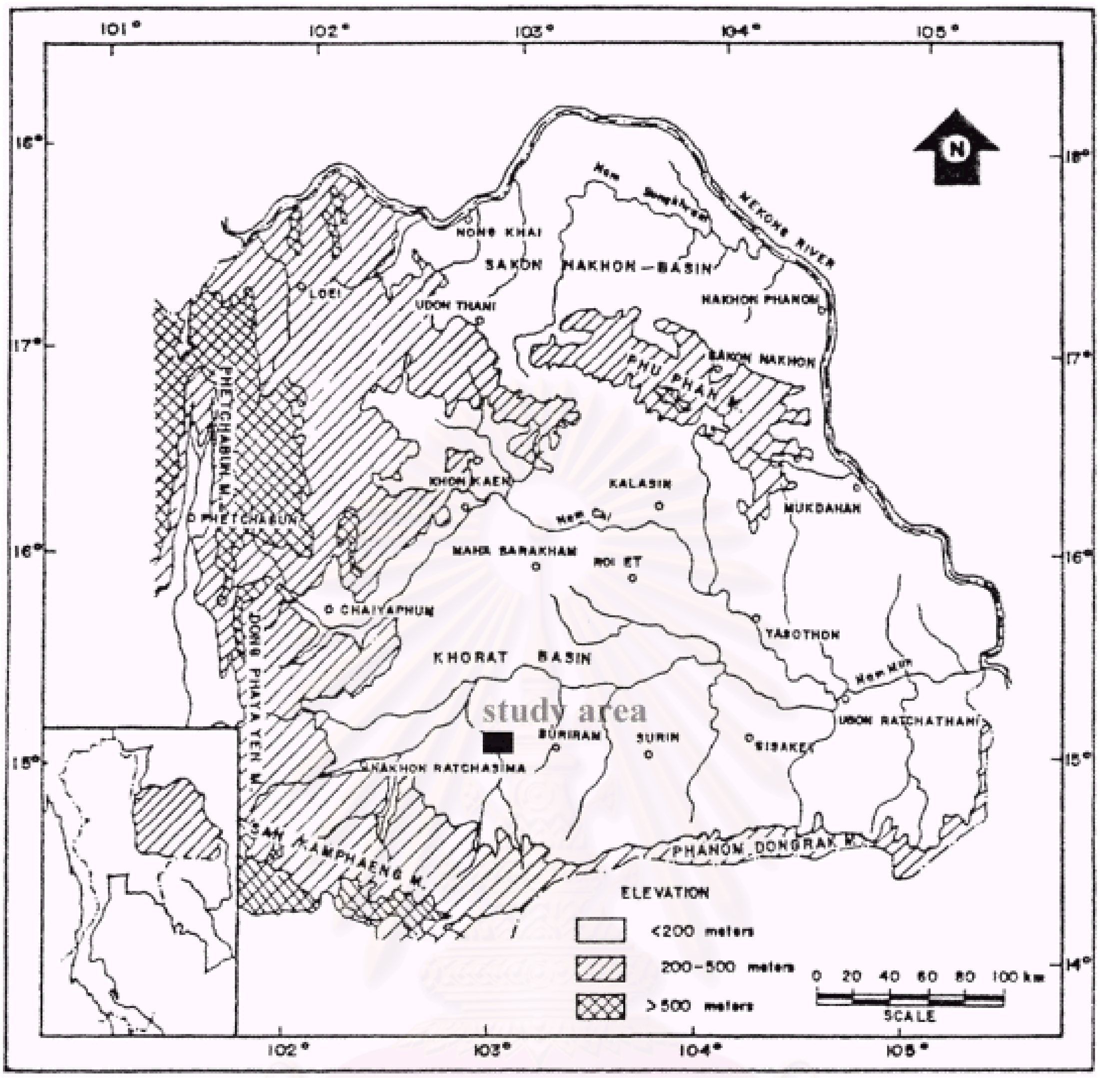

Figure 1.2 The location of study area in the Northeast Thailand; Khorat Plateau.

1. Flood plain: situated in the northern part and central along the Mun River, Lam Phang Chu, Lam Plai Mat, and Huai Ta Khong.
2. Terrace: consist of low terrace, middle terrace, and high terrace from north to south, respectively.
3. Slope: situate next of terrace in the southern and southwestern part.
4. Mountain: situate in the southern part as Ban Tat Mountain Range, Panom Dong Rak Mountain Range.

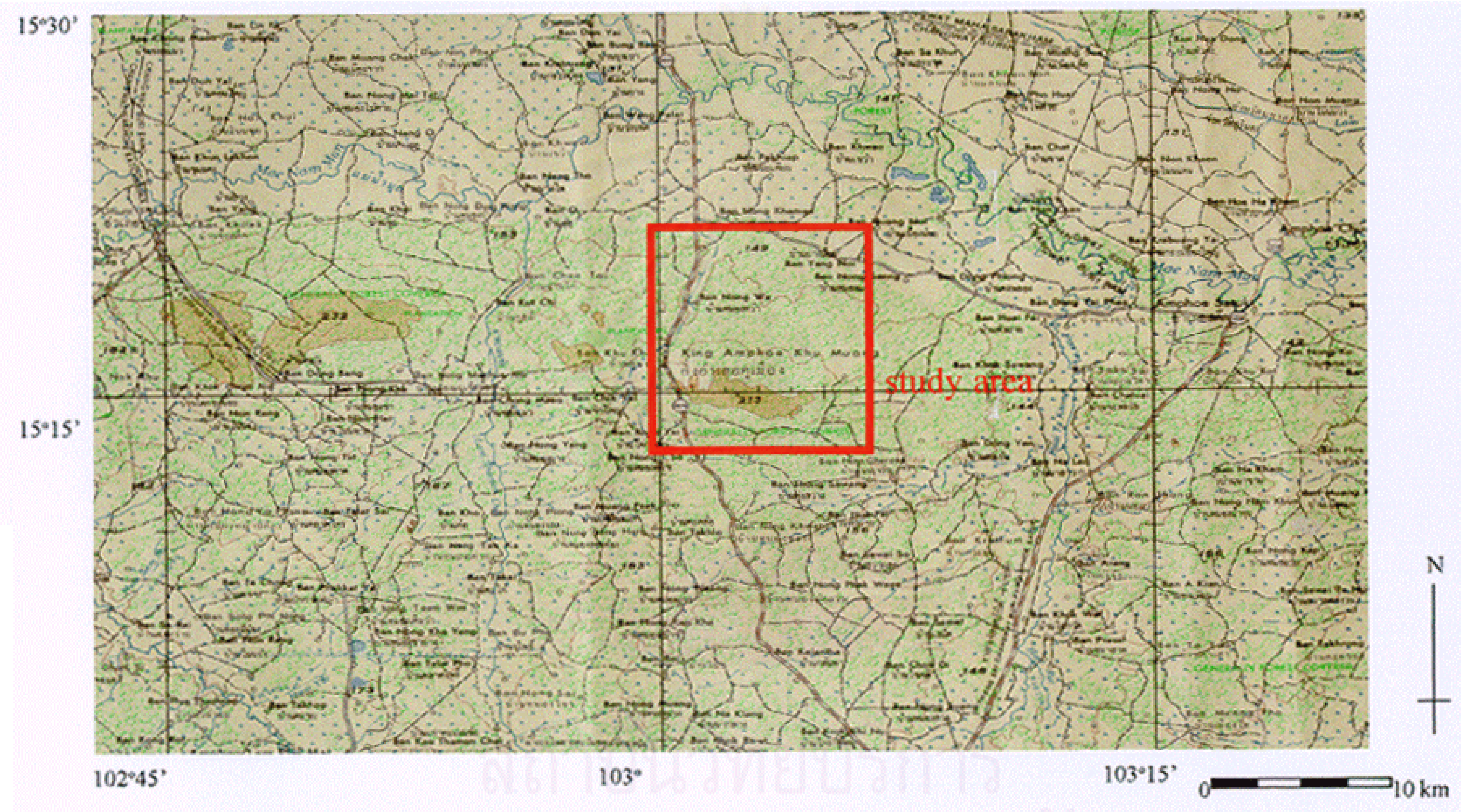

Figure 1.3 Location map scale 1:250,000 sheet ND 48-1 (Changwat Chaiyaphum)

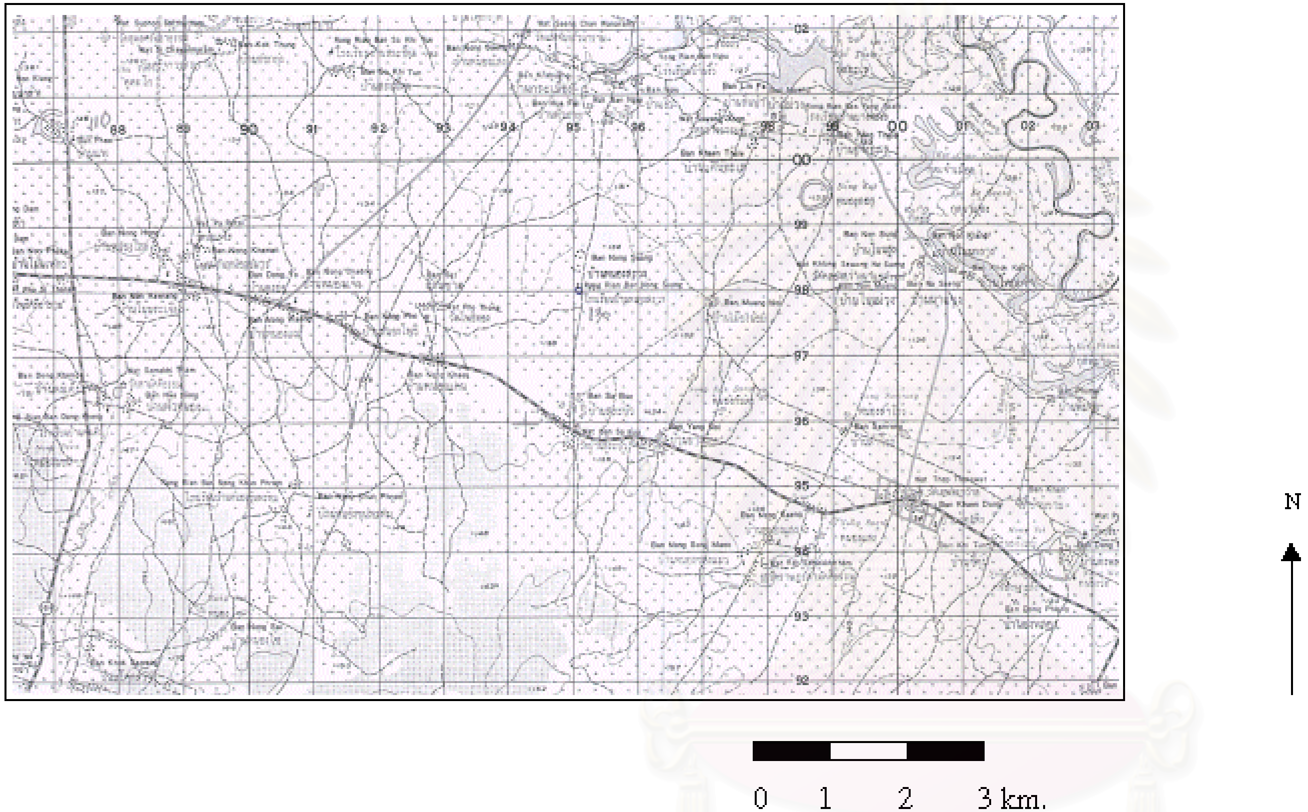

Figure 1.4 Topographic map scale 1 : 50,000 Amphoe Khu Muang, map sheet 5640III series L7017.

Figure 1.5 The characteristic of topography in the study area (the picture look to the south-east direction).

1.5 Climate

The climate of Changwat Buri Ram is tropical savanna. The precipitation amount around 20 year (1970-1990) from Nang Rong Climate Station is average 1,182 mm./year that influenced by northeastern monsoon and southwestern monsoon. The lowest temperature is 7.8 ^{o}C and the highest temperature is 41.8 ^{o}C. It can be divided the season into 3 seasons as:

Rainy: begin from June to middle October.

Winter: begin from middle October to middle February.

Summer: begin from middle February to May.

1.6 Natural resource

Most forests in Changwat Buri Ram are dipterocarp forests. The others are decidous forest, and evergreen forest that have valuable wood as: *hopea sp*. and *dipterocarpus sp*. They are distributed in Amphoe PraKhon Chai and Amphoe Khu Muang.

1.7 Water resource

The water resources in the study area can be divided into 3 categories as:

1. Rainwater: the rainwater in Changwat Buri Ram is influenced by southwest monsoon between June to October. During this period, it supplies approximately 86% of total yearly volume.
2. Surface water: the surface water of Changwat Buri Ram is consisted of 3 type as:
   2.1 Mun River: the Mun River is an important river of Changwat Buri Ram. It is originated from the valley of Khao Wong and Khao La Muang, which are parts of San Kampang Mountain Range, Amphoe Pak Thongchai, Changwat Nakorn Ratchasima. Its length is approximately 641 km., and the part that flow through Changwat Buri Ram is approximately 12 km.

2.1 Lam Plai Mat: Lam Plai Mat is originated from Khao Ma Kha, in the area of San Khampang Mountain Range, Changwat Nakorn Ratchasima. It flows into Changwat Buri Ram at Amphoe Nang Rong.

2.3 Lam Chi Noi: Lam Chi Noi is originated from Khao Panom Dong Ruk in the area of Amphoe Prasat, Changwat Surin. It flows to join the Mun River at the northern part of Changwat Buri Ram. It is used as a boundary of Changwat Buri Ram and Surin.

3. Groundwater: the groundwater is distributed in an extensive area of Changwat Buri Ram. The distinctive of groundwater reservoir area is the old terrace along the Mun River that consisted of gravel, sand, silt, clay, local lateritic soil, and laterite. The expected natural flow well yield is about 15-30 m^3/day (Panjasutharos, 1995). The quality of groundwater depends on the location of water path. The estimate TDS value is lower than 750 mg/l.

1.8 Mineral resource

In Changwat Buri Ram, there is no any economic mineral mining, except some mines, which are rock quarry.

1.9 Geological setting

The study area is a part of Khorat Plateau, Northeastern Thailand. This plateau extends northward and eastward boundaries across the Me Khong River to Laotain Territory. The NW-SE trending Phu Phan Anticlinorium divided the plateau into two basins: the Udon-Sakhon Nakhon Basin in the north and the Khorat-Ubon Ratchathani Basin in the south. The study area situates in the southern part of Khorat-Ubon Ratchthani Area.

Most of the Khorat Plateau surface exposures are of non-marine Mesozoic Khorat redbeds, the late Cretaceous eolian sandstone, and the younger redbeds

(Sattayarak et al., 1998, figure 1.6). The exposure at surface can be described as follow:

- Nam Pong Formation

The Nam Pong Formation is the lowest formation of the Khorat Plateau. The type locality of this formation is situated along the Nam Pong River, on the eastern side of the Phu Kradung Mountain. It consisted of soft, grayish red to pale red siltstone which make up 70% of the formation are interbedded with thick resistant beds of brownish sandstone and conglomerate. Cross bedding is conspicuous in the conglomerate and some sandstone beds. At this type section, the formation is about 1,456 m. thick.

- Phu Kradung Formation

The Phu Kradung Formation is lainover Nam Pong Formation. The type section is situated along the western slope of the Phu Kradung Mountain. It consisted of an alternated pink sandstone, red siltstone and red shale with occasional of thinly fine-grained conglomerates. The basal part of the Phu Kradung Formation is pelletal, micritic limestone interpreted as lacustrine in origin. The total thickness of Phu Kradung Formation is about 1,000 m.

- Phra Wihan Formation

The Phra Wihan Formation is lainover the Phu Kradung Formation. The type section is represented by the ridge below the top of Phu Kradung Mountain. It consisted of white to pink thick bedded well sorted medium quartz sandstone with some thin interbedded siltstone. The thickness of the formation is varying from 56 to 136 m.

- Sao Khua Formation

The Sao Khua Formation is lainover the Phra Wihan Formation. The type section is located at Huai Sao Khua between Udon Thani and Nong Bua Lamphu. It consisted of interbedded red to pink quartz sandstone and red to purplish shales. The thickness is varying from 404 to 702 m.

- Phu Phan Formation

The Phu Phan Formation is lainover the Sao Khua Formation. The type section is located at the Phu Phan Range. It consisted of white to pink well-sorted medium to coarse quartz sandstone with some conglomerate. The thickness of the formation is 82-183 meters.

- Khok Kruat Formation

The Khok Kruat Formation is lainover the Phu Phan Formation. The best sections are represented by borehole cored because this formation is poorly exposed. It consisted of interbedded moderately consolidated red siltstones, and red quartz sandstone and fine- grained conglomerate. The thickness of this formation is about 700 m.

- Maha Sarakham Formation

The Maha Sarakham Formation is uncomformably lainover the Khok Kruat Formation. There is a lithostratigraphy which represented this formation (figure 1.7). It consisted of halite, carnallite, sylvite, anhydrite and gypsum intercalating with deep reddish orange to purplish-red sandstone, siltstone and mudstone.

- Phu Tok formation

The Phu Tok formation that found in Phu Tok, Phu Langka, and Phu Wao in Changwat Nong Khai and Nakhonphanom was interpreted as eolian sandstone sequence. This formation can be correlated with the Upper Clastics of the Maha Sarakham Formation (Gardner et al., 1969)

- Younger Redbeds

The Redbeds consisted of claystone and siltstone with some sandstone and locally conglomerate that overlying on top of the Phu Tok formation (Japakasetr and Suwanich, 1982)

- Gravel Beds

The gravel beds are consisted mainly of rounded pebbles of vein quartz and gray to black chert up to 6 cm. and scattered with some rounded fragments of silicified wood.

From the Geological map scale 1:250,000 (Changwat Chaiyaphum), the study area comprises Maha Sarakham Formation on the south that consisted of sandstone, siltstone and mudstone, deep reddish orange, purplish red commonly with some white bleached along fracture, fine-grained, thin to thick-bedded, with rock salt, potash, gypsum, and anhydrite. The Quaternary terrace deposits on the center consisted of gravel, sand, silt, clay, and laterite. The Quaternary alluvial deposits on the north consisted of gravel, sand, silt, and clay (figure 1.8).

1.10 Hydrogeology

The characteristic of aquifers consisted of gravel and sand interbeded with fine to very fine sand, and clay. These aquifers cover about 3,000 km^2. from left abutment of the Mun River, Nakorn Ratchasima to Ubon Ratchathani (Panjasutharos, 1995). Source of sediments is brought in by the ancient river. They consisted of quartz, chert, sandstone, siltstone, shale, jasper and some petrified wood fragments scattered in the place. The topography is made of small hill and terrace along the river flood plain. The sedimentary beds are declined about 5^o to north. The distinctive characteristic of this aquifer is an artesian type of groundwater.

As figure 1.9, water quality of aquifer is quite good. The content of total dissolved solid is in the range 200-300 mg/l. The composition of chloride is less than 100 mg/l but the amount of iron is rather high varies from 1-10 mg/l. The natural flow rate of well are in the range of 15-30 m^3/d (Panjasutharos, 1995). The depth varies from 40 m to 200 m. and the piezometric level is about 0.3-1.0 m. above ground surface.

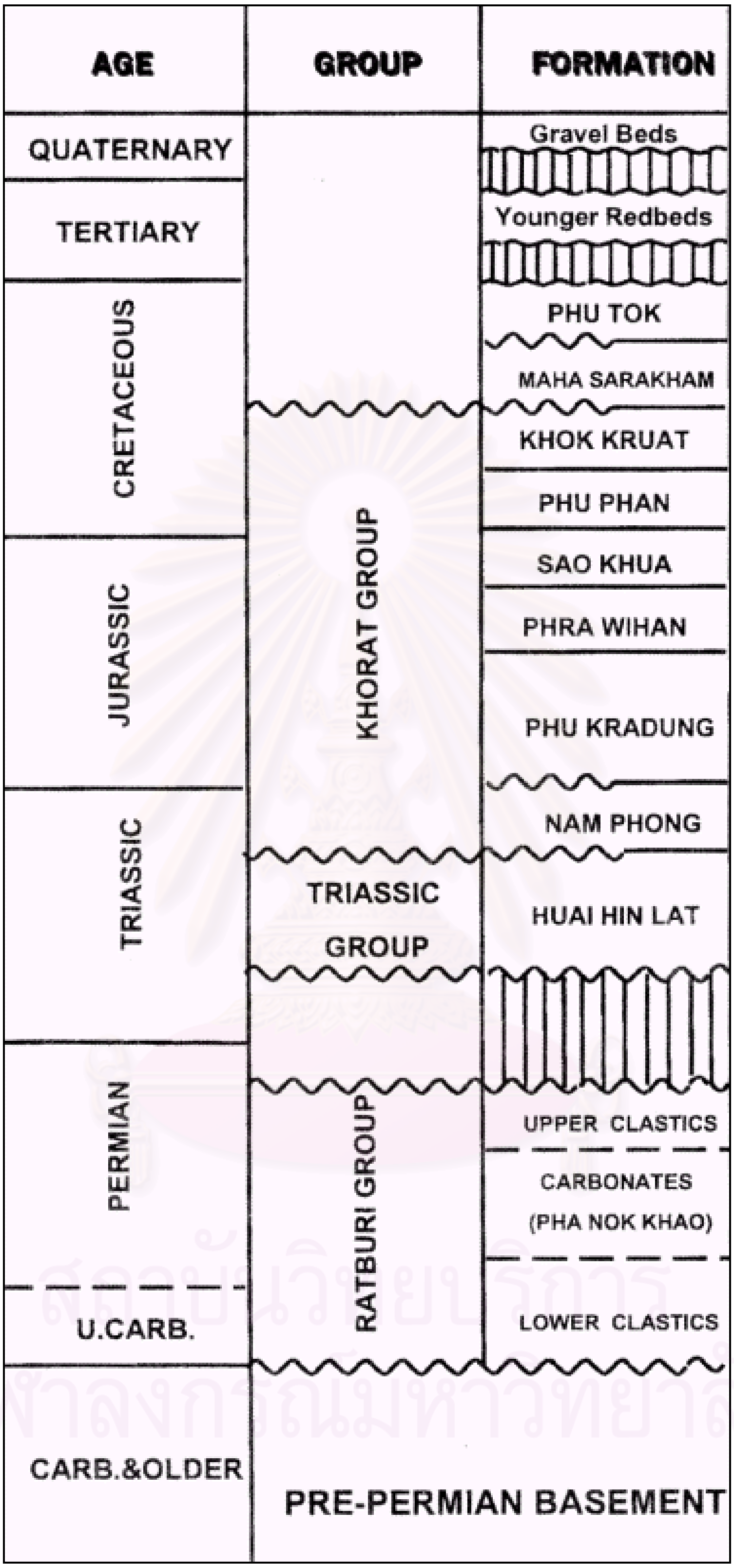

Figure 1.6 Generalized stratigraphy of Northeast Thailand. (Modified after Sattayarak, 1998)

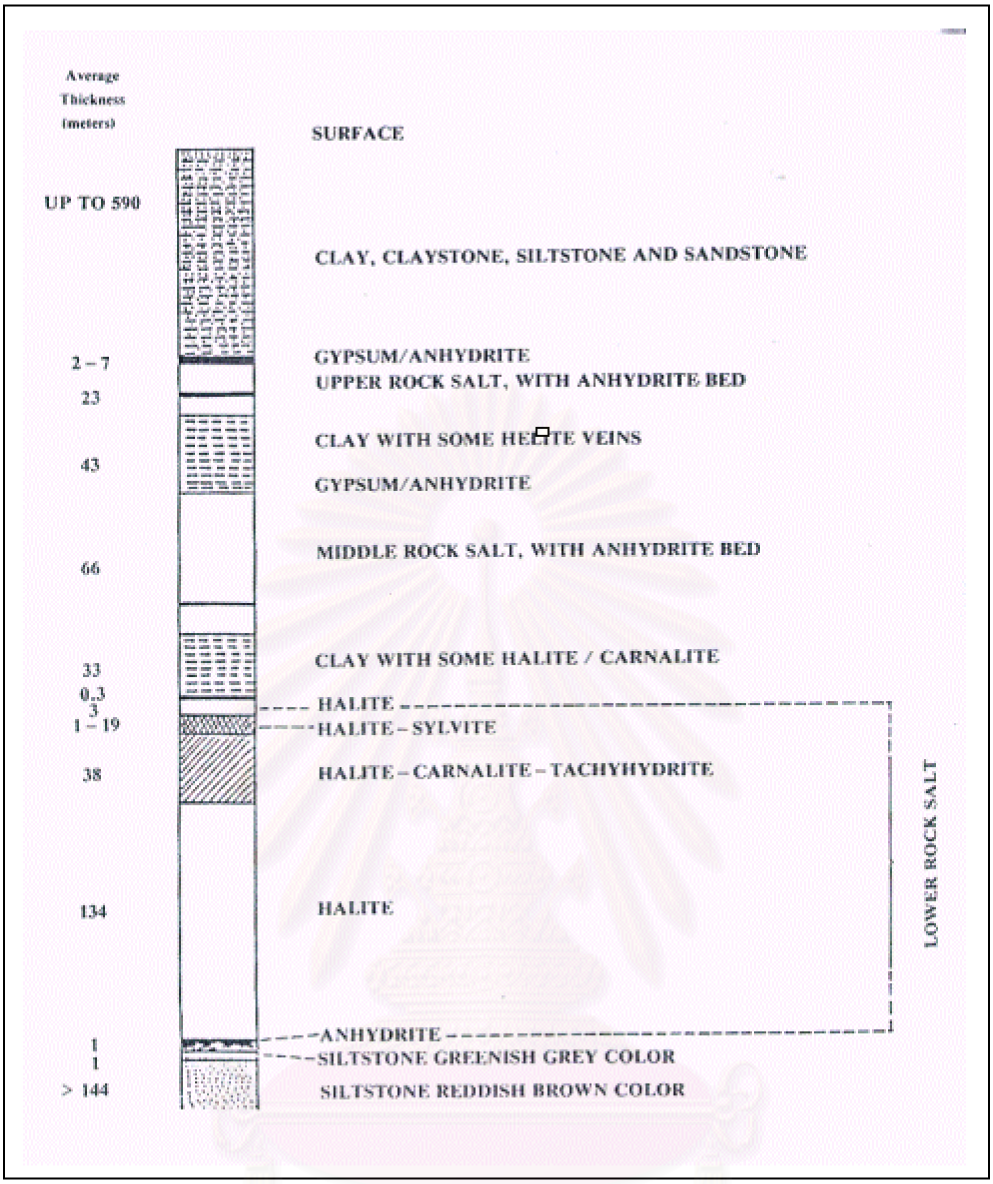

Figure 1.7 Schematic sequence of Maha Sarakham Formation (After Japakasetr,1979).

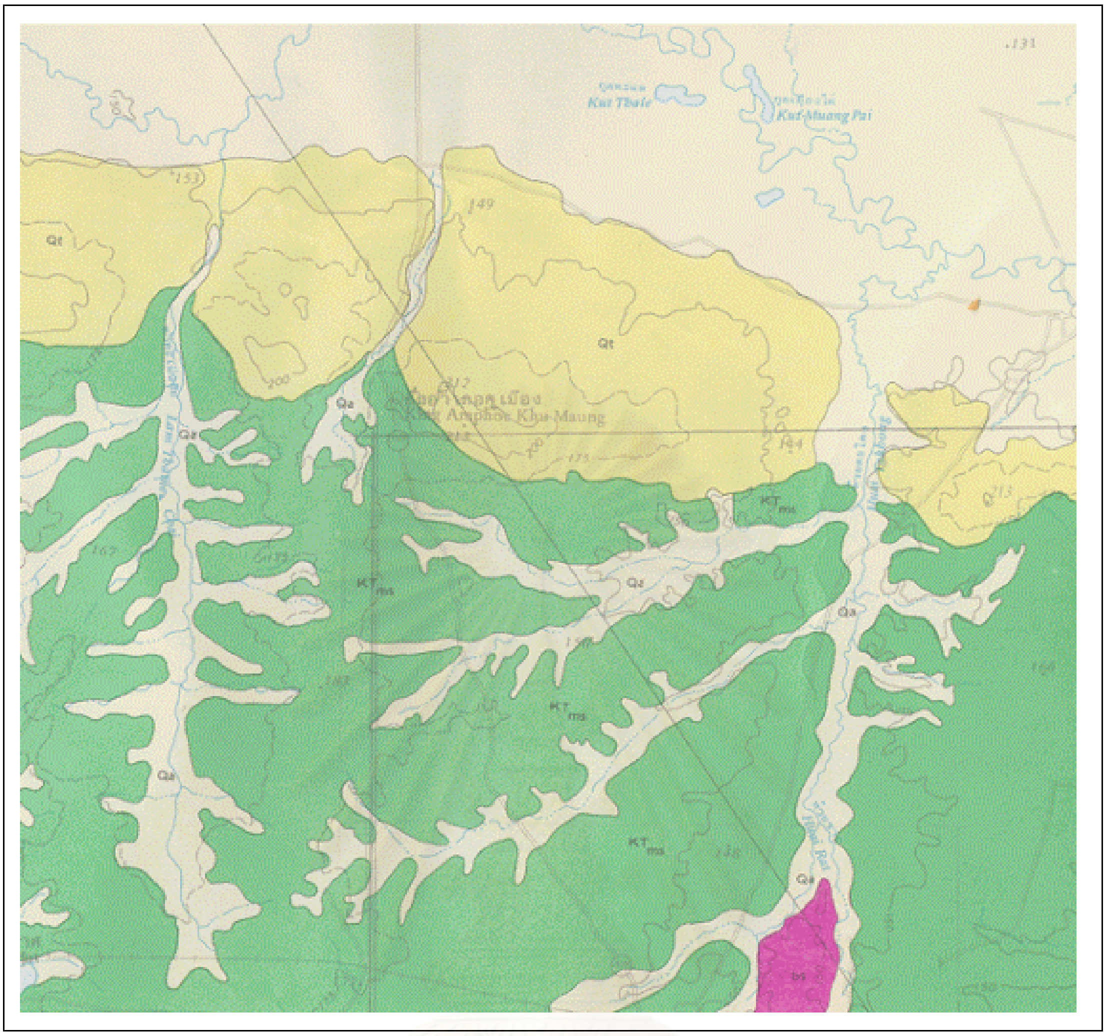

Figure 1.8 Geological map scale 1:250,000 (Changwat Chaiyaphum),

Explanation of figure 1.8

Alluvial deposits: gravel, sand, silt and clay.

Terrace deposits: gravel, sand, silt, clay and laterite.

Sandstone, siltstione and mudstone, deep reddish-orange, purplish-red commonly white bleached along fracture, fine-grained, thin to thick-beded, with rock salt, potash, gypsum and anhydrite.

Sandstone and siltstone, reddish-brown to pale-brown and purplish-brown, thin to thick-bedded, with lime nodule conglomerate.

Sandstone, white and pale-orange, commonly pebbly and cross-bedding, with siltstone and conglomerate.

Sandstone, reddish-brown and gray, micaceous; siltstone, reddish brown.

Sandstone, white and pink; orthoquartzitic, massive, cross-bedding, with some conglomerate beds.

Shale, reddish-brown and purplish-red, micaceous; siltstone and sandstone, reddish brown, with some lime noduled conglomerate.

Basalt

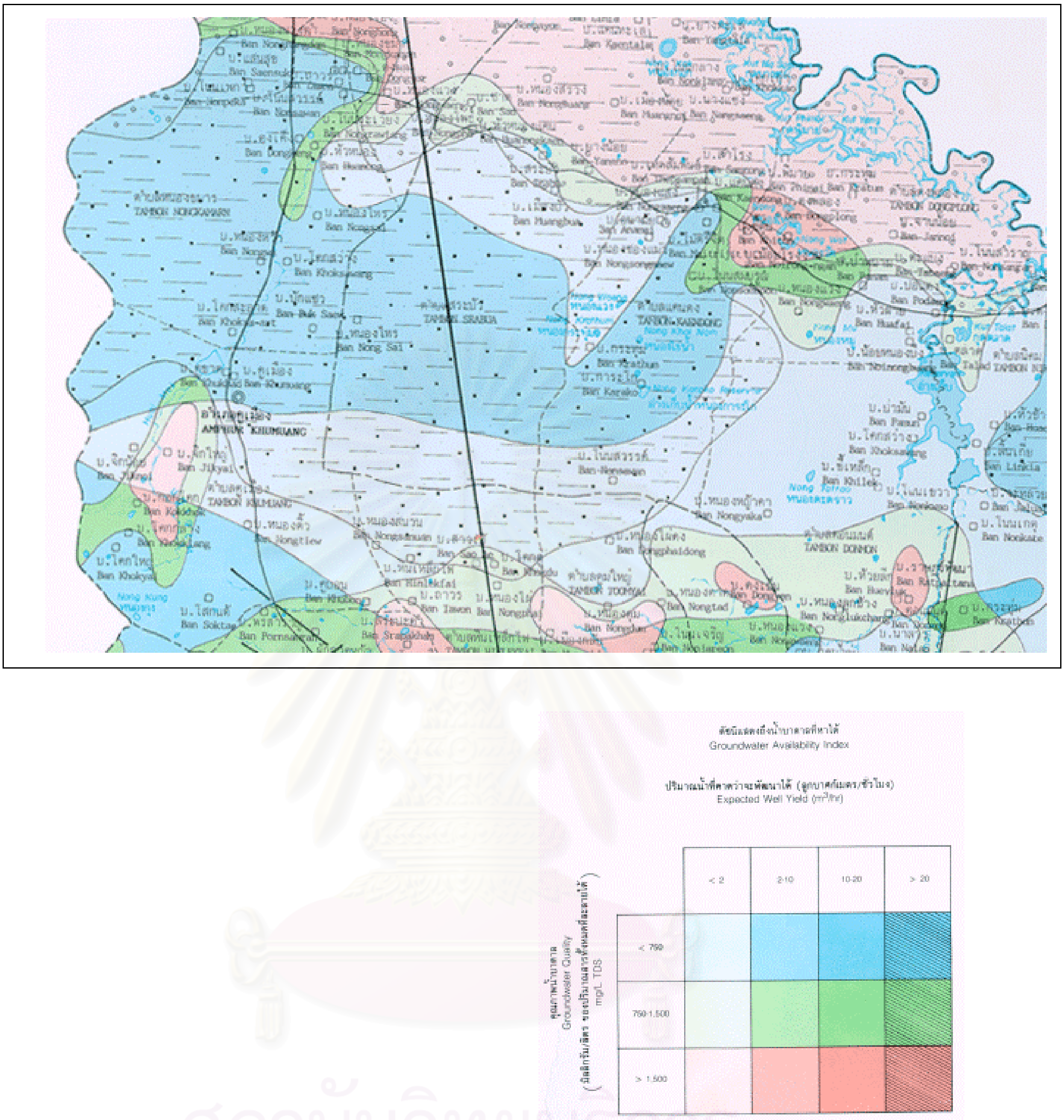

Figure 1.9 Groundwater map of Amphoe Khu Muang, Changwat Buri Ram (scale 1:100000).

Most of groundwater wells that situated at the elevation less than 160 m. above mean sea level are showed the artesian character because the landform feature looked like the valley basin that the elevation decrease from south of the Mun River to the channel and increase again to the north. The highest altitude is about 213 m. above mean sea level at Amphoe Khu Muang, Changwat Buri Ram. The lowest altitude is about 132 m. above mean sea level along the Mun River. The Quaternary geology of this area contains terrace sediments with various size from clay to pebbles, setting along the southern part of Mun River. The thickness is varying from 60 m. at the southern part of study area to 200 m. at Ban Kaen Dong, close to the Mun River.

This study area has long been in trouble since the municipal run short of water and also lacks of surface water and the quality of water always contaminated with salt water from the salt formation underneath. The DMR which is a unit of government office tries to solve this problem by creating the plan of groundwater development to relief the water shortage on both domestic and agricultural usages.

The study area is a part of the development projects which created to develop the groundwater resource of Tung Kula Ronghai under the responsibility of the DMR, Groundwater Division. The objective is to develop the groundwater to improve the agricultural activities in dry season and will lead to the improvement of infrastructure on both facility and quality.

1.11 Methodologies

The methodologies of this investigation are started by the literature survey (figure 1.10). This process is launched by survey the previous investigations and several background theory. The previous investigations are concerned about the Quaternary geology and the hydrogeology of the study area and adjacent. These documents are published in the several journals and conferences as appeared in the references. The background theory in this investigation is consisted of the descriptions of cuttings, E-logs and groundwater quality data that are described below.

After prepared this process, fieldwork and collecting data are operated. The fieldwork is in the area of Amphoe Khu Muang and King Amphoe Kan Dong, Changwat Buri Ram. In this area, the drilling rigs are operating and collecting data together with this running process. The data that collected in this area are cuttings, E-logs and groundwater samples. There are about 300 wells operated by Division of Groundwater, DMR. around the Amphoe Khu Muang and King Amphoe Kan Dong, Changwat Buri Ram. The distribution of wells is illustrated in figure 1.11. The depth of wells varies from 40 to 200 meters.

From the figure 1.10, the Quaternary geology and stratigraphy are used the above data as cuttings and e-logs data to construct the stratigraphic column and the paleoenvironment deposition.

Otherwise, the data are used together with the Quaternary geology and the stratigraphic column to construct the hydrogeology in the study area.

Finally, the results of the processes that mentioned above are used to construct the idealize groundwater model.

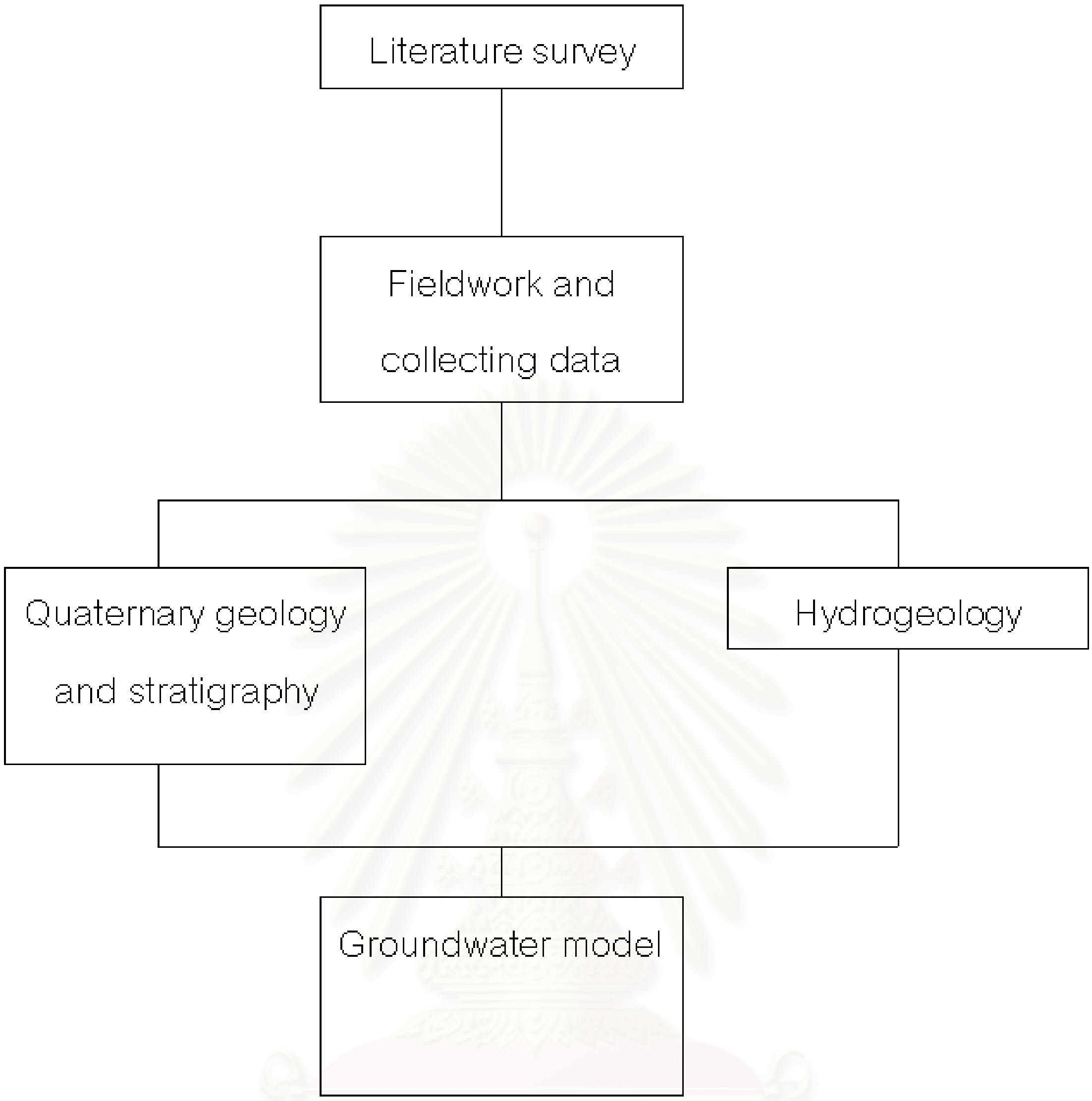

Figure 1.10 Diagram of the investigation process.

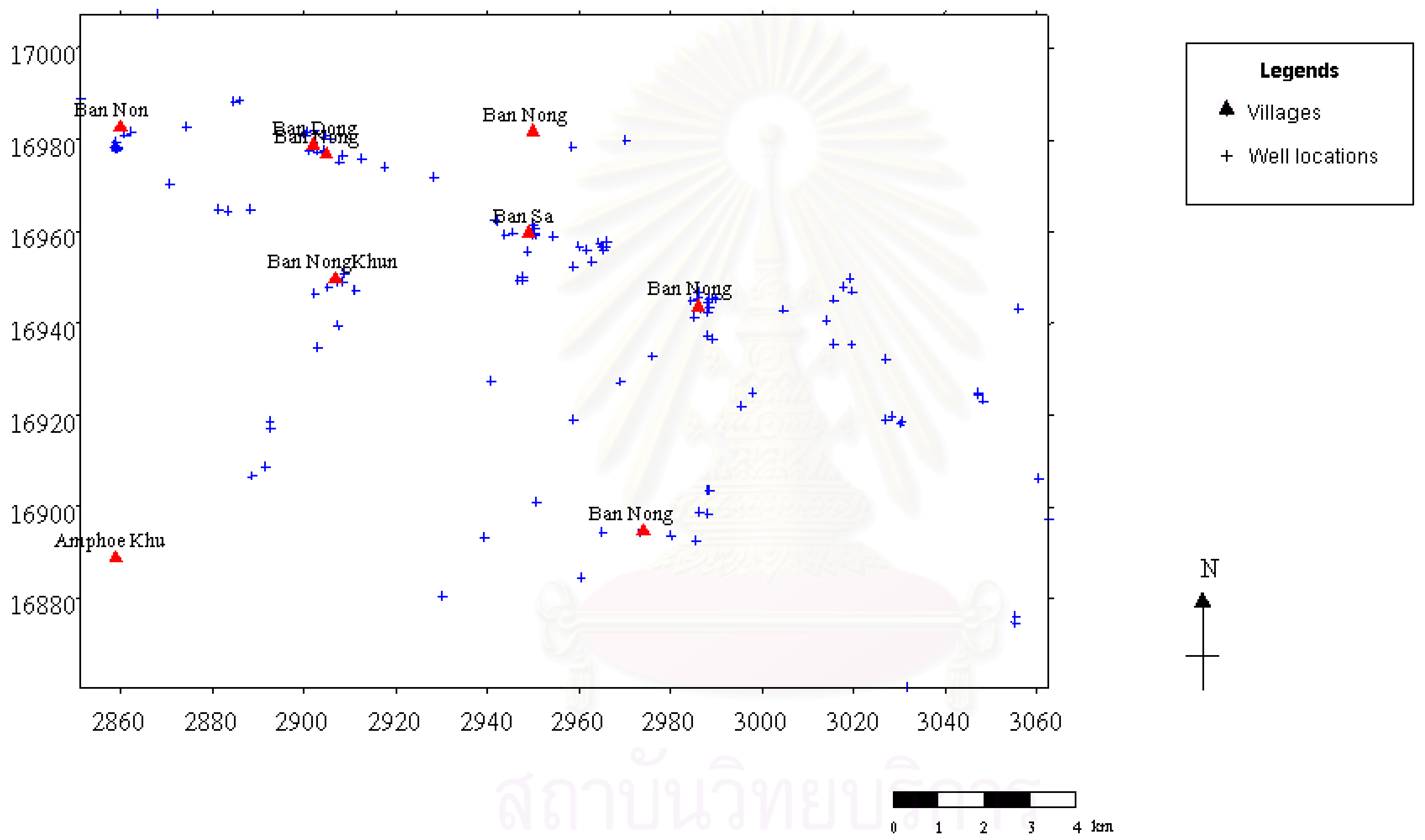

Figure 1.11 The distribution of groundwater wells in the study and adjacent area

Background theory

1.11.1 Cuttings

Nowadays, the cuttings are the products of rotary drilling (figure 1.12). It is worldwide used to explore the subsurface geology because this technology is safe, convenient, and reliable on application. The machine uses rotary motion in drilling and mud as drilling fluid was pumped through drill pipe, drill collar, and jet nozzles then bring back cuttings through annular flows. This is to clean the cuttings from the bottom of wells. After that, the well site geologist will collect these cuttings to study and describe the lithology (figure 1.13).

When the cutting samples are collected at the surface, the depth of each sample is also recorded. While the well is deepening, the discrepancy between the recorded depth always occurs. There are many effects caused from drill-operation to produce some errors such as the rate of drilling, the rate of mud circulation and the type of penetrated rock. But these errors can be calibrated by using the other data that recorded during penetrate such as E-logs data and etc. These data can provide the valuable data for stratigraphic column.

After collected the cuttings, its should be prepared earlier for examination because the samples are contaminated by drilling and mud. The preparation process should be done by washing the sample and separating the steel powder that may occur.

The cuttings in this study area were used to obtain importance description used to classify types of sediment, color, grain size, sorting, shape and compositions. These data are used to create the stratigraphic column, to correlate the stratigraphy and to simulate the sedimentary basin model.

Figure1.12 The drilling rig in the study area.

Figure 1.13 The cuttings from the groundwater well in the study area.

1.11.2 E-logs

The E-logs data are obtained from the groundwater well in the study area, which will be operated by Groundwater Division, DMR after the well are completed. There are two types of E-logs obtained in this study area as: spontaneous potential curve and resistivity log (figure 1.14).

SP log

The SP curve is recordings of naturally occurring physical phenomena. It records the electrical potential (voltage) produced by the interaction of formation connate water, conductive drilling fluid and certain ion-selective rocks (shale) (figure 1.15).

The SP curve is generally recorded in track 1 (left track) of the log. It is usually recorded in conjunction with some other log, such as the resistivity or porosity log. Although relatively simple in concept, the SP curve is quite useful and informative. Among their uses are the following:

1. Differentiate potentially porous and permeable reservoir rocks (sandstone, limestone and dolomite) from non-permeable clays and shales.
2. Define bed boundaries and permit correlation of beds.
3. Give a qualitative indication of bed shaliness.
4. Permit the determination of formation water resistivity.

The SP curve is a recording versus depth of the difference between the electrical potential of a movable electrode in the borehole and the electrical potential of a fixed surface electrode.

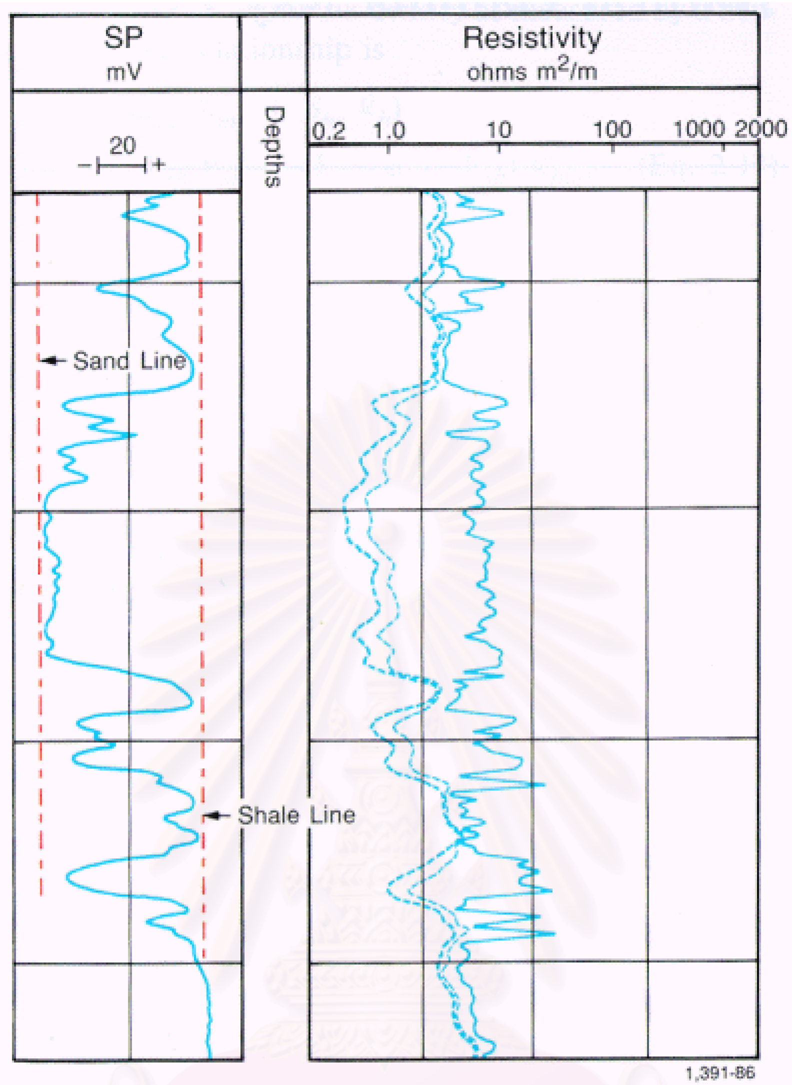

Figure 1.14 Schematic of SP log and resistivity log.

Opposite shales the SP curve usually defines a more-or-less straight line on the log, called the shale baseline. Opposite permeable formations, the curve shows excursions from the shale baseline; in thick beds, these excursions (deflections) tend to reach and essentially constant deflection defining a sand line. The deflection may be either to the left (negative) or to the right (positive), depending primarily on the relative salinity of the formation water and of the mud filtrate. If the formation water salinity is greater than the mud filtrate salinity, the deflections to the left. For the reversed salinity contrast, the deflection is to the right.

A SP curve cannot be recorded in holes filled with nonconductive muds because such muds do not provide electrical continuity between the SP electrode and the formation. Furthermore, if the resistivities of the mud filtrate and formation water are about equal, the SP deflections will be small and the curve will be rather featureless.

Resistivity logs

Resistivity logs measure the effect of an artificial electric current, which is produced in the logging truck and transmitted to the formation through electrodes in the sonde. A large number of electrode spacing and arrangements are used in subsurface resistivity logging. Most resistivity logs use a combination of three or four electrode arrangements. This is done to achieve varying depths of current penetration.

Resistivity of a fluid-saturated rock to the passage of electricity is a function of three primary factors. First, the salinity of pore fluid, second, the porosity of the rock and third, the temperature of the rock and fluid. Other factors, which are of importance, are the mineralogy of the solid material and the geometry of the pore spaces.

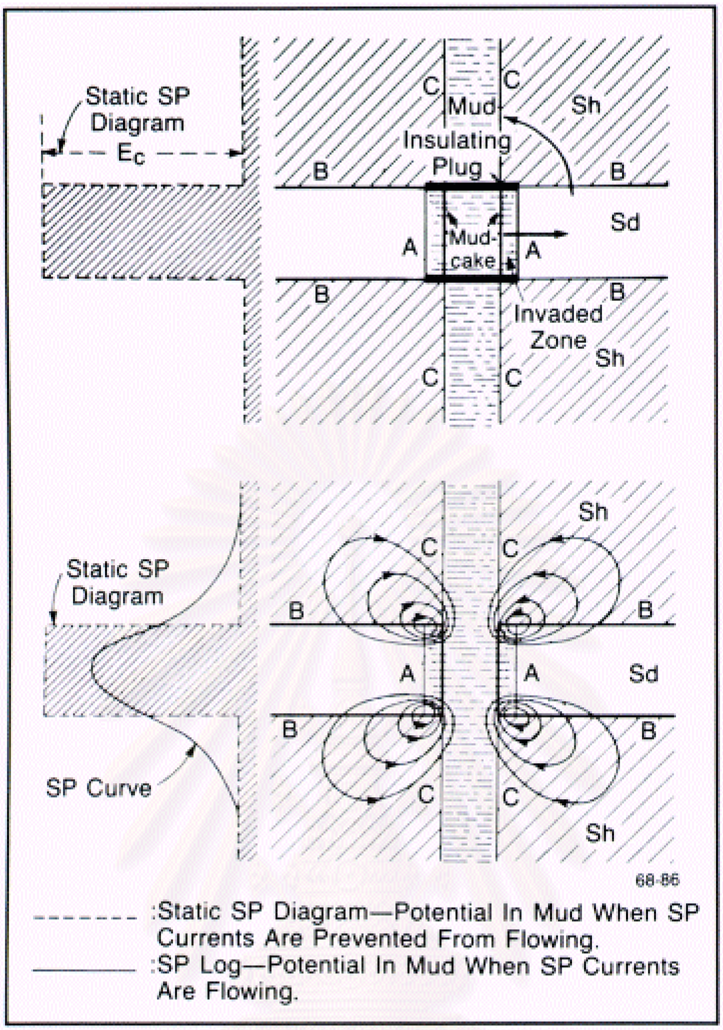

Figure 1.15 Schematic representation of potential and current distribution in and around a permeable bed.

Resistivity logs are used to interpret rock types, to aid in correlation and to estimate the chemical character of pore fluid. The dense, nonporous rocks, such as limestone, will have very high resistivities. In contrast, highly porous materials saturated with saline water will have low resistivities. Clay minerals will generally reduce the resistivity because ions which cluster on the mineral surfaces will greatly increase the current-carrying capacity of the sediment. In most logs extremely low resistivities are recorded opposite shale and clay beds.

As in SP logs, the resistivity log will commonly have distinctive configurations for certain beds or horizons. Characteristic forms of the curve may correspond to lithologic changes too subtle to detect by normal techniques of geologic logging. Thus, the resistivity log along with the self potential log constitutes one of the most useful means of lithologic correlation.

The study area used these SP and resistivity logs to locate the zone of perforation, to correlate the units of sediments and to calibrate the depth of each cutting sample.

1.11.3 Water quality data

The water quality data are analyzed by Analysis Division, DMR that obtained the water samples from the groundwater well in the study area. They analyzed pH, electrical conductivity and several components such as Fe, Mn, Cl, NO_3, F, TDS (total dissolved solid) and TH (total hardness). The explanation of the water quality are elaborated below:

pH: the pH refers to the activity effective concentration of hydrogen ions in the water, expressed as the negative logarithm (base 10) of the H^+ activity in the moles per liter. At a pH of 7 (15^oc), the H^+ activity is 10^{-7} mol/l and the solution is considered neutral. When the pH is less than 7, the solution behaves as an acid (particularly below pH 4). Above pH 7, the solution reacts like a base. Most natural waters are within a pH range of 6 to 8.5 (Hem, 1970).

Electrical conductivity: the electrical conductivity is the ability of groundwater to conduct an electrical current. It is the reciprocal of resistance and is measured in mhos. The conductance of groundwater is depended on the temperature, type of ions present, and concentration of various ions. Pure water has a conductance of 0.055 micromho at 25^oc. Distilled water commonly has a conductance at 0.5 to 5.0 micromhos. Rainwater will usually range from 5.0 to 30 micromhos. Ocean water range from 45,000 to 55,000 micromhos, and normal groundwater range from 30 to

2,000 micromhos (Davis and De Wiest, 1966). The unit microsiemens/cm is equivalent to micromhos/cm. Because the definition of specific conductance already specifies the dimensions to which the measurement applies, the length in the units is often omitted in practice.

The components analysis of groundwater in this study area is analyzed the quantity of Fe, Mn, Cl, NO_3, F, TDS, and TH. The variation of each components always effect the quality of water.

Iron: most iron in solution is thought to be ionized; however, organic complexes may be important in surface water. If the pH of the water is below 3.0, the iron should occur in the ferric state (Fe^{3+}). Above this pH, ferric iron may be present as a complex iron. If the Eh is not too high, water contains ferrous iron. The concentration of ferrous ions in groundwater is probably limited by the solubility of ferrous carbonate, but it still ranges between 1 and 10 ppm if the pH is between 6.0 and 8.0, and if the bicarbonate concentration is relatively low.

When groundwater containing ferrous ions comes in contact with the atmosphere, the following reaction can occur.

$$2Fe^{3+} + 4HCO_3^- + H_2O + 1/2O_2 \longrightarrow 2Fe(OH)_3 + 4CO_2$$

Inasmuch as some contact with air almost always takes place during sampling and the amount of oxygen needed is small, this reaction will occur in most samples taken of natural water. Although the reaction tends to lower the pH somewhat, the solubility of ferric hydroxide is so low in the normal pH range that most of the iron will be precipitated (Davis and De Wiest, 1966).

Manganese: Manganese is released into groundwater by the weathering of minerals such as biotite and hornblende. When exposed to the atmosphere Mn^{2+} is oxidized to form much less soluble hydrated oxides. Most waters contain less than 0.2 mg/l of manganese.

Chloride: Chloride is a minor constituent of the earth's crust, but a major dissolved constituent of most natural water. Sodalite and apatite are the only common minerals in igneous and metamorphic rocks, which contain chloride as an essential constituent; although micas, hornblende, and natural glass may also contain significant amounts. Liquid inclusions in rocks and minerals are another source of chloride from igneous rocks. The foregoing sources are generally thought to be insufficient to account for the amount of chloride, which must have been contributed to the oceans since they were first formed. The chloride in evaporite deposits and in ocean water at present may be as much as 100 times the amount of chloride which would be expected in the basis of the volume of rocks which must have been weathered to produce the amount of sodium present. It is probable that the small, but more or less continuous, contribution of chloride from volcanic gases may account for much of the chloride, which has accumulated in seawater.

Most chloride in groundwater comes from four different sources. First, chloride from ancient seawater entrapped in sediments; second, solution of halite and related minerals in evaporite deposits; third, concentration by evaporation, of chloride contributed by rain or snow; and fourth, solution of dry fallout from the atmosphere, particularly in arid regions. A locally important source may be from volcanic water in hot spring systems. Quantitatively speaking, the most important source of chloride in near-surface water appears to be chloride transported in the atmosphere and carried to earth by rain or snow. The chloride content of most rain near coastal areas ranges between 3 and 6 ppm This diminishes rapidly to 1.0 ppm or less 100 miles inland, and to 0.3 ppm or less 500 miles inland. Thus it is inferred that most chloride in coastal areas is from oceanic sources. The rain and snow condense around minute dried particles of ocean spray which are continually being carried aloft from turbulent areas on the ocean surface. As air masses migrate inland, dust particles from terrestrial source become more important as nuclei of condensation, and the ratio of chloride to other ions in rain decreases accordingly. If, however, dust is rich in chlorides, such as is true near desert playas and cities which use salt to control street icing, the chloride content of rain may be locally high even in the interior of continents.

All chloride salts are highly soluble, so chloride is rarely removed from water by precipitation except under the influence of freezing or evaporation. Chloride is also relatively free from effects of exchange, adsorption and biological activity. Thus, if water once take chloride into solution, it is difficult to remove the chloride through natural processes.

Chloride concentrations found in natural water vary between about 0.1 ppm in arctic snow to 150,000 ppm. in brines. Continental rain and snow may contain 1.0 to 3.0 ppm, but probably average less than 1.0 ppm. Shallow ground water in regions of heavy precipitation generally contains less than 30 ppm of chloride. Concentrations of 1000 ppm or more are common in ground water from arid regions.

Nitrate: Although igneous rocks contain small amount of soluble nitrate or ammonia, most nitrates in natural water come from organic sources or from industrial and agricultural chemicals. An additional minor source is from nitric oxides produced by lightning discharges. Nitrogen is an essential constituent of protein in all living organisms. When organic material decomposes through bacterial action, the complex proteins change through amino acids to ammonia, nitrites, and finally to nitrates. Some of the nitrates produced may be leached by percolating water and eventually reach the ground water: however, most nitrate is probably used by plants soon after it is released by bacterial action. Certain plants, such as alfalfa and peas, have bacteria living on root nodules, which fix nitrogen gas from the atmosphere. The nitrates thus formed are commonly in excess of the plant's needs, so a surplus is available for leaching.

Nitrate compounds are highly soluble, so nitrate is taken out of natural water only through activity of organisms or through evaporation. Common nitrate concentrations in water range from 0.1 to 0.3 in rainwater to as much as 600 ppm in ground water from areas influenced by excessive applications of nitrate fertilizer or runoff from barnyards. Normal groundwater contains only from 0.1 to 10.0 ppm nitrate.

Fluoride: Fluoride, also one of the halogen group, is quite different from other elements in the group in its geochemistry. Unlike chlorine, bromine, and iodine, many of the compounds of fluorine have a low solubility. Natural concentrations of fluoride commonly range from about 0.01 to 10.0 ppm. A few water samples have been analyzed which have more than 10.0 ppm; the highest reported is 67 ppm from the Union of South Africa. The natural concentration fluoride appears to be limited by the solubility of fluorite (CaF_2), which is about 9 ppm fluoride in pure water. It has been observed, however, that water high in calcium does not contain more than about 1 ppm of fluoride.

Total dissolved solids: Total dissolved solids in a water sample include all solid material in solution, whether ionized or not. It does not include suspended sediment, colloids, or dissolved gases. Theoretically, if all dissolved solids were determined accurately by chemical tests, total dissolved solids would be the numerical sum of these constituents.

A related measure is the residue left after evaporation followed by drying in an oven at 180^{o} C, or less commonly at 110^{o} C, for one hour. The solid material left after evaporation does not coincide completely with material originally in solution. Gases are driven off; bicarbonate is converted to carbonate; sulfate may be deposited as gypsum which traps some of the water; and small amounts of magnesium, chloride, and nitrate may be volatilized. Nevertheless, the residue after evaporation, along with electrical conductance, affords a rough check on the accuracy of the sum of total dissolved solids.

Natural water range from less than 10 ppm of dissolved solids for rain and snow. There is more than 300,000 ppm for some brine. Most of domestic and industrial use water should be less than 1,000 ppm, and water for most agricultural uses should be below 3,000 ppm. The final classification of water in relation to potential use, however, should be based on concentrations of individual ions rather than on total dissolved solids.

The total hardness (TH) results from the presence of divalent metallic cations, of which calcium and magnesium are the most abundant in groundwater. These ions react with soap to form precipitates and with certain anions present in the water to form scale. Because of their adverse action with soap, hard waters are unsatisfactory for household cleansing purposes; hence, water-softening processed form removal of hardniss are needed. The degree of hardness in water is commonly based on the classification listed in table 1.1

Hardness, mg/l as CaCO3	**Water class**
0-75	Soft
75-150	Moderately hard
150-300	Hard
Over 300	Very hard

Table 1.1 Hardness classification of water (after Sawyer and McCarty).

1.12 Previous Investigations

-Quaternary geology

Loffler et al., 1983 reported the geomorphological development of the Thung Kula Ronghai. The sedimentation is derived from the tectonic evolution that made it changed in base level (figure 1.16). Therefore, the alluvial sediments are filled into the larger valley system, superimposed onto these tectonically controlled processes were changed follow climate and environmental processes with alternating drier and more humid phase. This is reflected in the sediments by the different character of its.

Khantaprab et al., 1985 reported the environmental geology of Thung Kula Ronghai that generally underlain by Maha Sarakham Formation. The area can be divided into 3 main types, notably, the active floodplains, the alluvial plain and the gently undulating sandy areas. Basalt from Buri Ram and limestone from Pak Chong or Chum Phae are the nearest sources of crushed rocks, whereas sand, gravel and laterite deposits are abundant. The groundwater can be found in the unconsolidated aquifer of Holocene alluvium. The sediments in this area are low organic matter and low nutrient content.

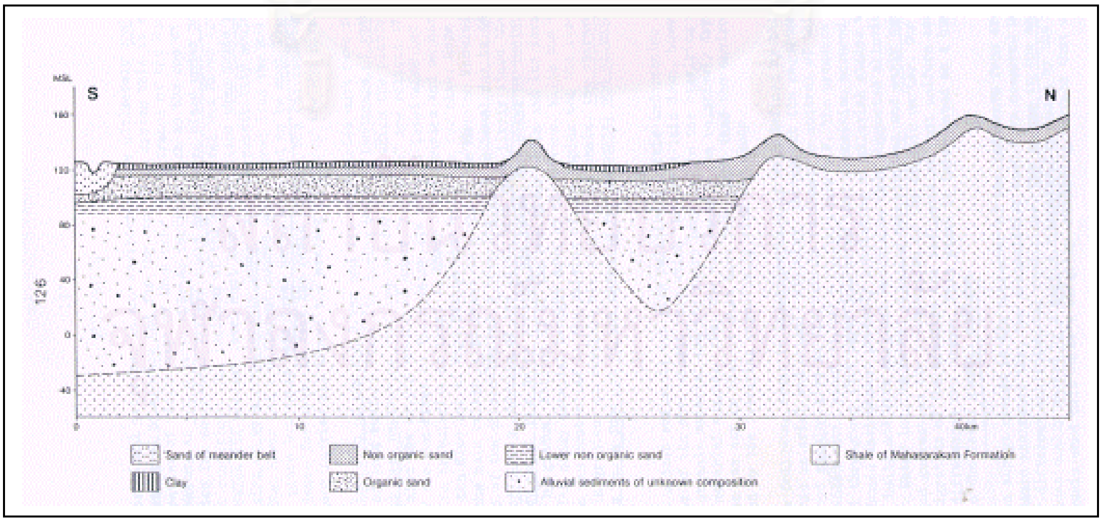

Figure 1.16 Idealized stratigraphic cross section across Tung Kula Ronghai (Loffler, et al, 1983).

Piyasin S., 1985 reported the problem of stratigraphic classification and environments of deposition of Khorat Group. He reported which Sattayarak, 1983 illustrated the Upper Khorat Group and Mahasarakham Formation, Underlying the Phu Tok or Upper Claystone that is separated by the lithology and Japakasetr and Suwanich, 1982 given nomenclature the upper claystone similarly to the Borabu Formation by using the well K-66 as a type location. He concluded that Phu Tok and Upper Claystone Formation should be eliminated, and propose drilled hole K-66 as a type section of Borabu Formation.

Wongsomsak, 1986 reported the Quaternary stratigraphy of this work that can be described with the help of x-ray diffraction techniques together with the degree of weathering and the major clay minerals contents. And the other tools are tektites, petrified wood and lithology. It can be divided into three chronostratigraphic formations. There are “Unnamed” formation, the Kham Sakae Saeng formation and the Khu Muang formation. The ages of these formations are in the range between Paleocene to Holocene.

Udomchoke., 1988 reported the Quaternary stratigraphy of the Khorat Plateau area, northeastern Thailand (figure 1.17). The stratigraphic units of the Khorat Plateau is consisted of 9 units. There are the weathered rocks of the Khorat Group at the basement. The other are basalt unit, gravel beds unit, organic sand unit, red and yellow loessial-soil unit, lake bed and swamp deposits unit, wind blown sand unit, flood deposits unit and alluvium unit, respectively. The age determination of this Quaternary sediments are in the range between 3.28 +/- 0.48 million year BP in diabase from Phu Fai, Changwat Srisaket to 1,900 +/-100 year BP in Embedded mollusc shell from Ban Non Chai, Changwat Khon Kaen. The environment of deposition is vary. There are volcanic, fluvialtile, lacustrine, wind blown and the deposition climate is humid and warm alternate with dry and cool climate.

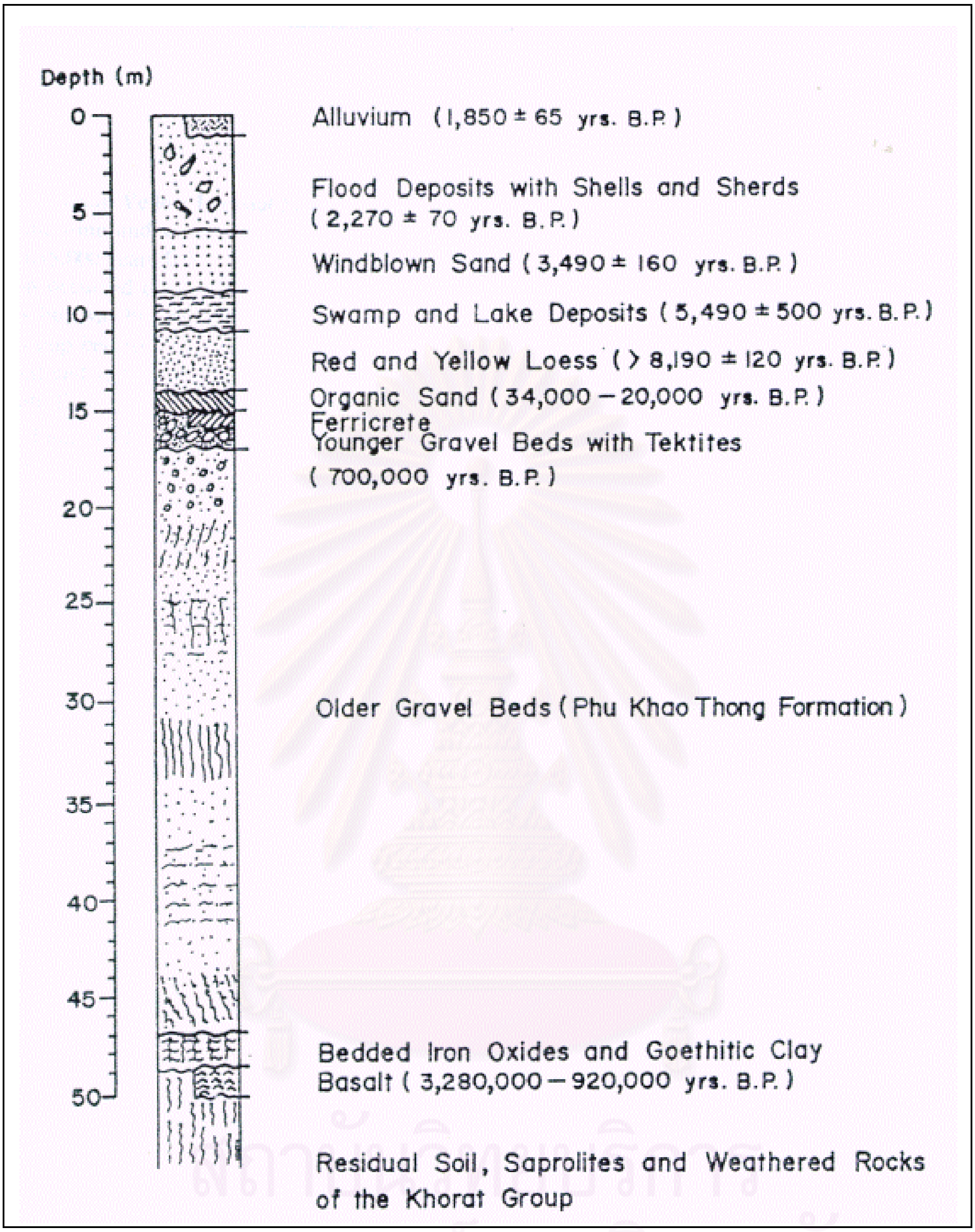

Figure 1.17 Quaternary stratigraphic section of the Khorat Plateau area (Udomchoke, 1988).

Rattanajarurak, 1990 reported the rock salt Maha Sarakham Formation in the northeastern Thailand is separated from the Khorat Group by using the environment of deposition. It is composed of three beds of rock salt which are Lower Salt, Middle Salt and Upper Salt. The Lower Salt that basal anhydrite is overlying Khok Kruat Formation and the Upper Salt is underlying Phu Tok Formation. The age of this Formation is about late Cretaceous. In this Formation, There are many problem controlled by structure that affect to the groundwater. The important problem is the transportation of or salt from rock salt to the surface that turned the groundwater into brine and the briny groundwater that left salt on the soil surface. This problem is caused by the failing of vegetation covered and needed to have a better management.

Sattayarak et al., 1998 reported the tectonic and basin development of the northeast Thailand. The northeastern Thailand comprises two main areas: the mountains of the Loei Petchabun Foldbelt and the Khorat Plateau. The Foldbelt comprises Permian flysch, molasse, platform carbonates with occasional Permo-Triassic granite/volcanic rocks and Mesozoic outlier. The Plateau composes a sequence of Permo-Carboniferous carbonate and shallow marine siliciclastic which are unconformably overlain by Triassic Pre-Khorat lacustrine sequence, the continental Khorat Plateau is floored by various kinds of Redbeds, for instance the non-marine Mesozoic Khorat Redbeds, the Cretaceous Eolian sandstone and the younger redbeds.

The tectonic evolution and basin development of the northeast Thailand can be divided in to 4 units as the first: the indosinian orogeny I that made the Permian sediments folded, thrusted, uplifted, and eroded. Higher degrees of tight fold and thrust are severed to the west in the Nam Duk Basin and decreased eastward into the Khorat Plateau suggesting compression from the west. Second, the indosinian orogeny II that occurs locally mild compression along major faults at the end of Triassic, causing a minor inversion and erosion of Triassic sediments. Third, the uplifting of Loei-Petchabun fold belt that constructed the Phu Phan Anticlinorium. The Khorat Basin was terminated and two land-locked, hypersaline sedimentary basins were formed, the

Nakhon Thai to the west and Maha Sarakham Basin to the east of the fold belt respectively. Finally is the Himalayan orogeny that occurs by the collision between India and Asia in the Early Tertiary. Permian and Triassic strata were partly inverted and uplifted further, producing a large wave length fold of the Khorat sequence, including the Phu Phan Anticlinorium, and uplifting of the Khorat Plateau.

- Hydrogeology

Ramnarong, 1985 reported the aquifers of the northeastern Thailand are the rocks of the Mesozoic age. This Mesozoic Rocks are predominantly sandstone, siltstone, shale and conglomerate. Groundwater can be found mainly in cracks, joints and bedding planes. Average yield of well is less than 5-10 m^3/hr, but in some area are more than 50 m^3/hr. in the complex jointing system. The alluvial aquifer and the other main rivers in this region are good aquifer.

Wongsawat and Panjasutharos, 1990 reported (in Thai) the geohydrology of southern area of Mun River, average relief is 280 MSL. And ascending to about 100 meters at Amphoe Tha tum, Changwat Surin. The thickness of this sediment is about 50-100 meters. The yield is in the range of 20-50 m^3/hr. In various areas, the groundwater well is penetrated in confined aquifer that yield 1-3 m^3/hr. The height of the piezometric head is average about 1-2 meters above surface. The quality of water is good which the total dissolves solids is not over 600 mg/l.

Panjasutharos, 1995 reported the artesian flowing wells in unconsolidated rock aquifer along the Mun River that it is the gravel-sand aquifer on the left abutment of the Mun River from Nakhon Ratchasima to Ubon Ratchathani Province. The approximate thickness is 100 meters. The flow rate of 2-4 inch well with several depth of about 30 meters varies from 15-30 m^3/day. The aquifer of over 3,000 km^2 yielded a good quality water of reasonable flow rate (figure 1.18).

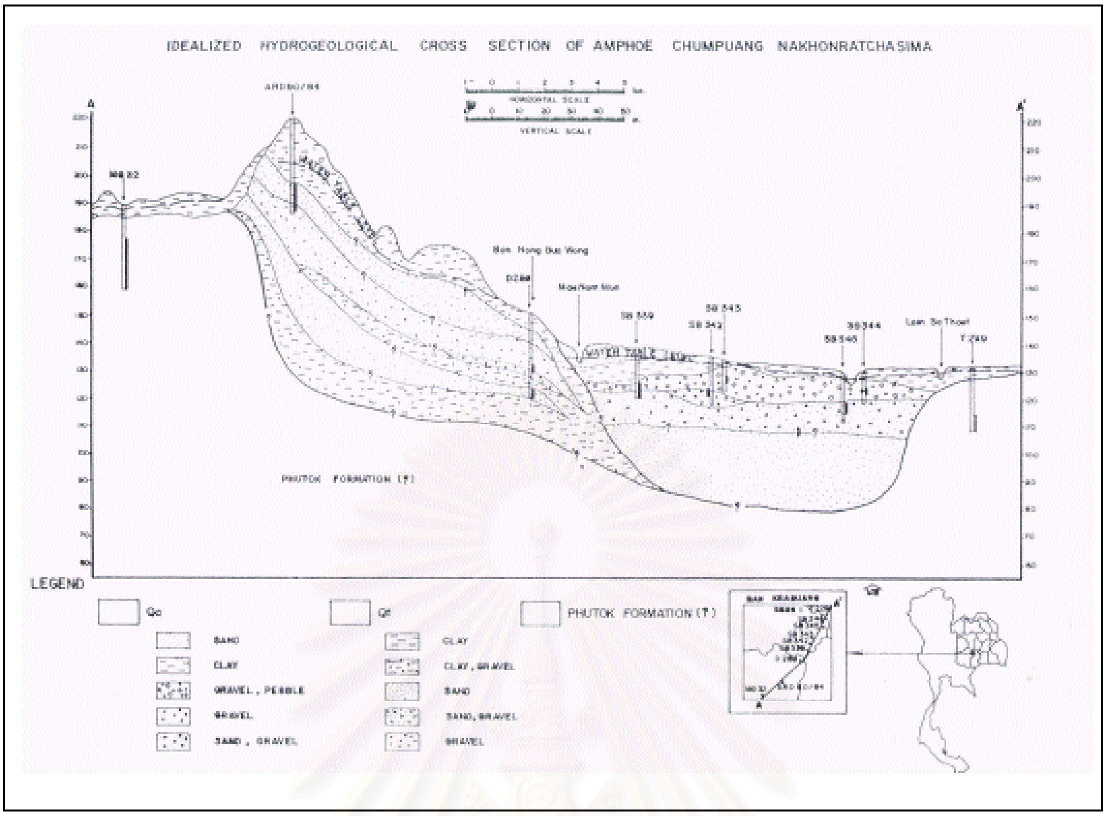

Figure 1.18 Idealized hydrogeological cross section of Amphoe Chumpuang, Nakhon Ratchasima (Panjasutharos, 1995).

Chapter II

Quaternary Geology and Stratigraphy

2.1 Review of Quaternary geology of the Khorat Plateau

The Khorat Plateau situated at northeastern part of Thailand. It comprises an area of about 170,000 km^2, approximately one-third of the total area 514,000 km^2 of the country. There are mainly the Mesozoic rocks that formed the basement and covered by the Quaternary deposits. These deposits have been investigated by many of geologist to solve the process of deposition, erosion, and stratigraphy that occur in several area in the Khorat Plateau. The process of depositional environment is particularly fluvialtile deposit and some area is eolian deposit. The conclusion of the papers on stratigraphy is not yet settled but some data (description of sediment and environment of deposition) have a close resemblance.

The papers that related to the Quaternary deposits of Khorat Plateau are composed of various documents. In this report, some documents have been selected to review and discuss in the previous chapter. The documents involved the Quaternary geology of Khorat Plateau, Khon Khan Province and Buri Ram Province. It can be summarized the Quaternary stratigraphy of the Khorat plateau into 5 main units as follows (figure 2.1):

1. weathered profile of the Khorat Group
2. gravel beds
3. organic rich sand
4. red/yellow loess
5. alluvial deposits

(from young to old in an ascending orders)

The lowest, weathered profile of the Khorat Group is found in most stratigraphic columns, continuous from the rock of upper most Khorat Group. It composed of various types of sediments within the formations that formed basement of this area. Next is gravel beds that overlies the weathered profile. This bed can be found in most of the Quaternary deposit in the Khorat Plateau. These beds can be referred to the high-energy paleoenvironment. It formed the important reservoir of groundwater. Next are the organic rich sand beds. These beds characteristic represented the fluvio-lacustine deposits and the distribution of these beds can be found in only some part of the plateau. This is why it disappeared in many stratigraphic sections or columns. Next are red/yellow loess beds that refer to the dry climate and windblown deposition unit from the paleoenvironment. This type of deposits was found to cover almost the entire plateau. The uppermost unit is the alluvial deposits which is the youngest sedimentation unit of the Khorat Plateau represents the deposition of the recent time.

2.2 Quaternary geology

The Quaternary geology of this area is analyzed and excerpted from several data as the previous works, the observation of the areal landform, and the descriptions of the groundwater-well cuttings and E-logs. These are the data to be used as database on the interpretation and correlation for their areal extension and environment of deposition of the Quaternary geology.

The previous works that mentioned above can be correlated the Quaternary geology of the study area to the gravel beds that is similarly laid over the weathered profile of the Khorat Plateau.

The characteristic of landform are obtained from the analyses of topographic map together with field observation on areal landform expression indicated that the highest elevation of the area is on the southern margin, which gently sloped down into flood plain and the channel of Mae Num Mun to the north. The contrast or the diffence of the elevation within the area does not seem, to be noticeable, the slope is so gentle, and it disappeared on the map.

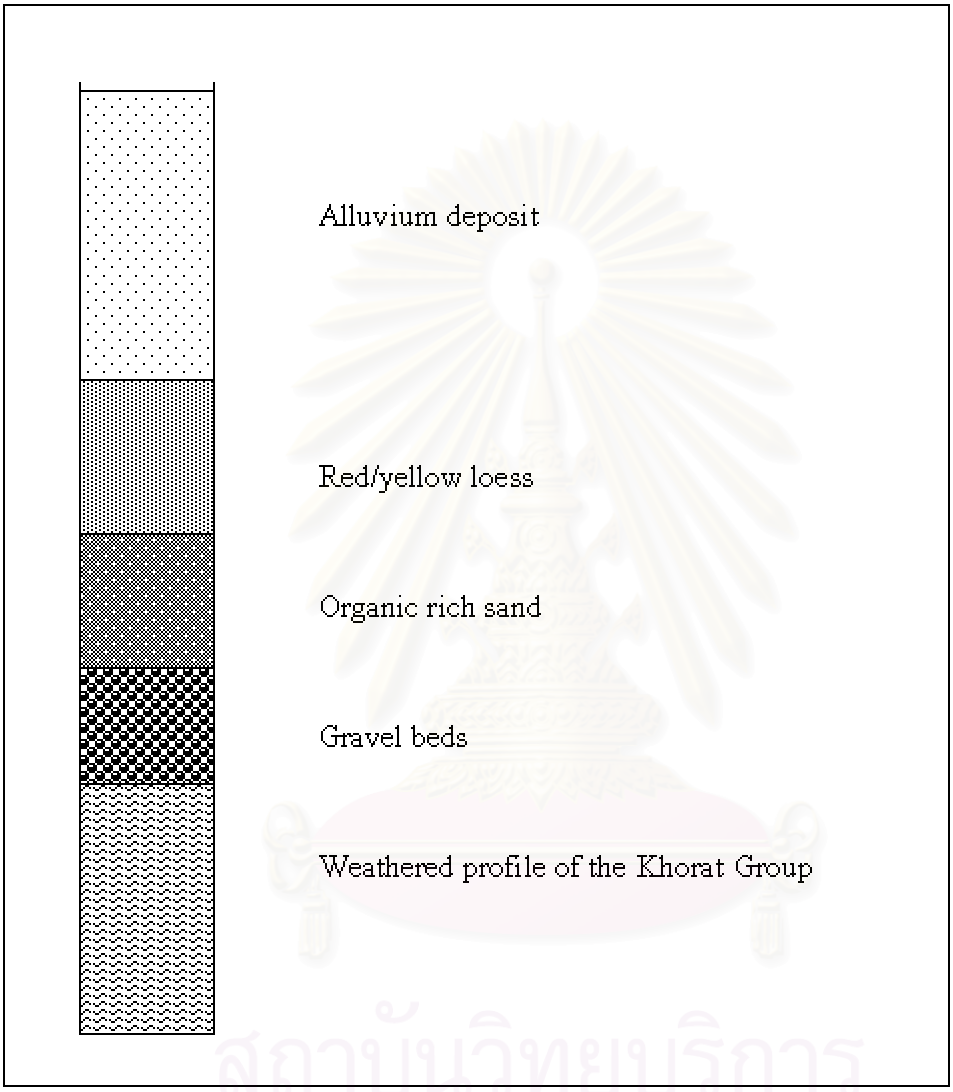

Figure 2.1 The Quaternary stratigraphic column of the Khorat Plateau (not to scale).

Well cuttings data which obtained from this study area are the main sources of evidences used to constructed and explained their framework to some extent. Some sedimentary textures and grains characteristic combined with E-logs data are used as a key evidence to elucidate and proof for their framework. The descriptions of cuttings are illustrated in the appendix VII. Finally, these data are used as evidences to confirm the framework of the Quaternary geology of this area.

The Quaternary geology of the area obtained from the geologic map scale 1:250,000 Changwat Chaiyaphum is illustrated in figure 1.6 as alluvium deposit that consisted of gravels, sand, silt, and clay. From the cuttings that drilled in various depths, The sedimentary characteristics obtained from these wells are similar and almost identical to the Quaternary alluvial deposits. Most of the sediments are unconsolidated sediments. From the lowest section lied with red clays which is consolidated to some extent. Ascending upward is dark gray clay which laid down unconformably on top of red clays. There is another dark gray unconsolidated layer consists of gravels and sand, the sand is well sorted and seems to be distributed throughout the study area. The next overlying sedimentary layers is gray clay and on top of it is laid down by another unconsolidated gravels and sand which interbedded with thin layer of clay. Within thin layer, which some pieces of peats are found. Next of the overlying sediment is thin brownish gray clay that have its distribution similar to the dark gray clay in the bottom part. The upper sediment is yellowish brown gravels and sand that intercalated with clay distributed throughout the area. It possessed some distinct characteristic of recent alluvium sediment.

From the above mentioned, it can be explicated the type and distribution of the Quaternary sediments within the area. The types of Quaternary sediments are consisted mainly of quartz sand and clay. These two types of sediments are illustrated as alternation. There are some differences characteristic of the sediment that can be used to separate the sedimentary layer such as color, sedimentary texture, grain size, and etc. These are the tools that used to classify the sedimentary rock into 2 formations.

The thickness and the position of sedimentary formation are varied probably due to their paleogeography and paleoenergy within the basin.

2.3 Geology and Stratigraphy

The stratigraphic sequences of this area are constructed from well cuttings and E-logs obtained. These samples evidence are observed and examined for their distinct characters on their physical appearance such as type of sediment, color, grain size, grain constituents and also some sedimentary texture which might be able to use in separation and correlation on each layers.

From these well cuttings, it indicated that the sediments are unconsolidated and it can be divided into 2 types as sand and clay. They are found to be distributed throughout the area with some characters. It's possession indicated the fluvialtile origin. The depositional pattern appeared as sand deposits in alternated with clays. Some sand deposits does appear as finning upward sequences which indicates point bar deposit. The geometry of sand is elongated on east-west direction and thickening in the central body is also conformed with the present day Mae Num Mun. The evidence from cuttings contained some gravels which may be part of channel lags deposit of the point bar sequences. The alternated clays deposits probably worked out from the associated flooded plain into a shallow lake deposits to form seal for the sand reservoir.

From the examination and analysis of cuttings samples it can be divided into 6 units as

The first unit is the semiconsolidated red clay, forming as the basement rock (figure 2.2). The main constituent of this unit is quartz of very fine grained of silt. Some freckle of gypsum is found by X-ray diffractometer (appendix III) in this unit. The thickness of this unit is unknown.

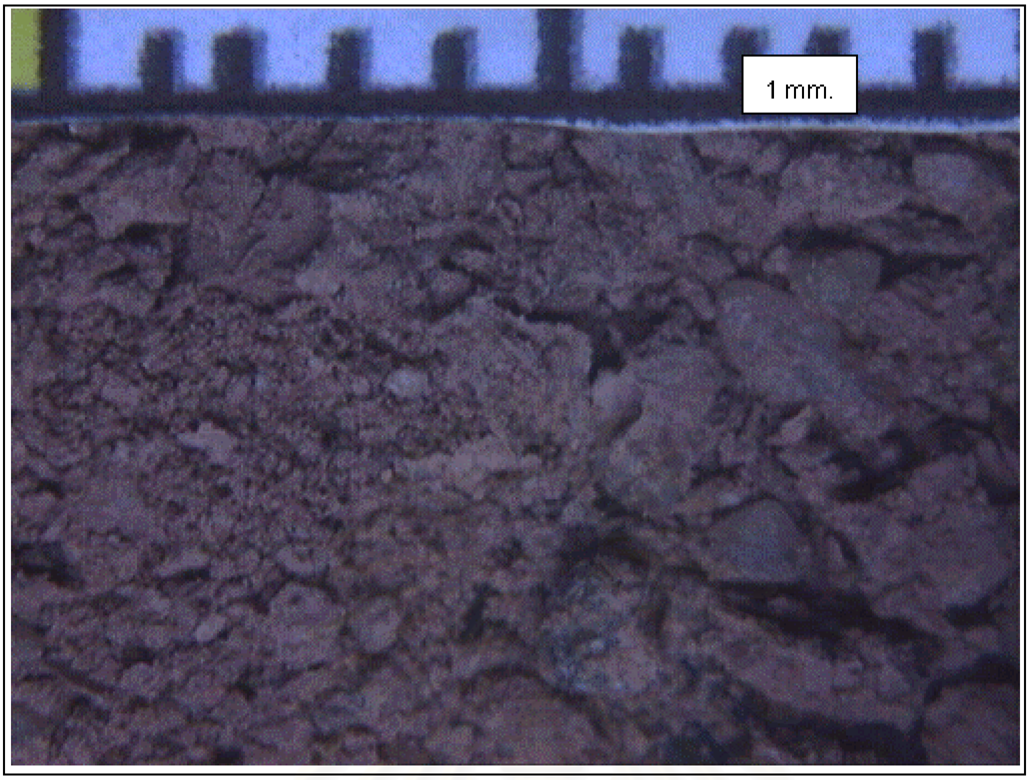

Figure 2.2 The first unit that showed red clay from the well No. RTA 16.

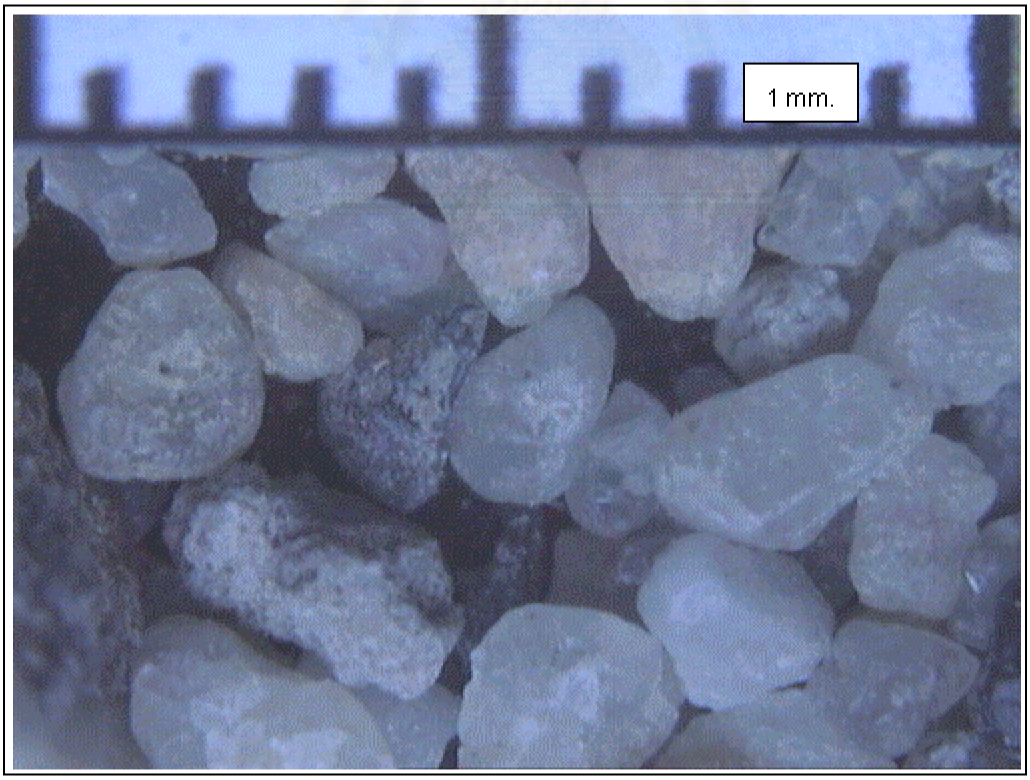

Figure 2.3 The second unit that showed coarse sand from the well No. RTA 16.

The second unit is consisted mainly of thick clay which laid down to the north and confined to the northern portion. Thick gray sand is laid down of top of clay with more extensive in its areal extent than the underlain clay (figure 2.3). However this second unit of clay and sand are of gray color and laid down unconformably on top of unit one which is basement rock of red clay.

The sediments of unit one and unit two can be differentiated from each other by either color of red or gray or by type of sediments as sand and clay or silt only. The other characteristic of this unit are the sand made up of moderately well sorted, subangular to subrounded, the sediments are made up of various size from fine sand to pebbles. There is some evidence of finning upward from cuttings and E-logs shown from this unit.

The third unit of clay bed was laid down on top of the second unit (figure 2.4), it can be distinguished from the previous unit by its lighter color of pale gray to gray. The sediment of this unit consisted of thick clay bed of 5 meters thick. There appeared to contain some thin layers of sand within its thick clay bed.

The fourth unit is like the second unit only the color is slightly paler, from pale gray to light yellow. The main type of sediment is sand with some clay interbeded within the average thickness of this unit is 40 meters (figure 2.5). The coarse grained sediments are moderate to well sorted, subangular to subrounded. Grain size is varied from fine to very coarse sand with some pebbles occasionally. The compositions are mainly made up with quartz more than 95 %. The rest are chert, jasper and some rock fragments.

The fifth unit is composed mainly of clay with some sand and sandy clay interbeded (figure 2.6). The average thickness of this unit is 5 meters. The color of this unit is gray to yellowish gray which also used the slightly difference in color to distinguish it from the third unit. The main composition is clay with some quartz sand. The upper most unit is composed of sand and clay of the recent alluvial deposits which topsoil is also included (figure 2.7). The average thickness of this unit is 30 meters.

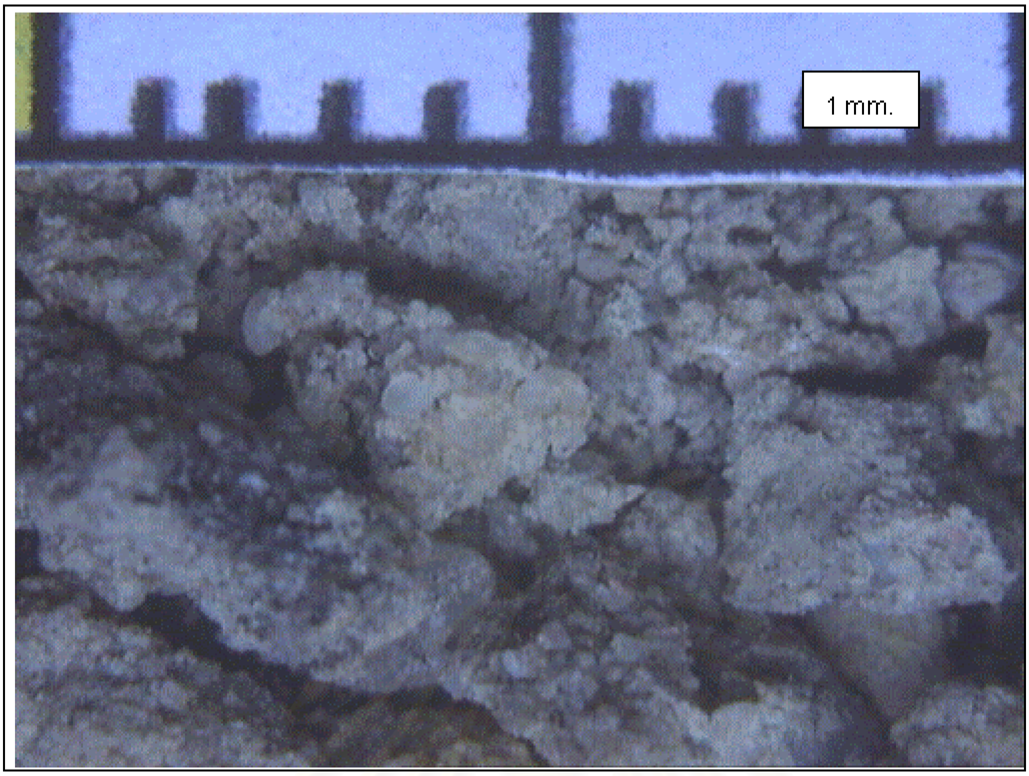

Figure 2.4 The third unit showed the pale gray to gray sediment.

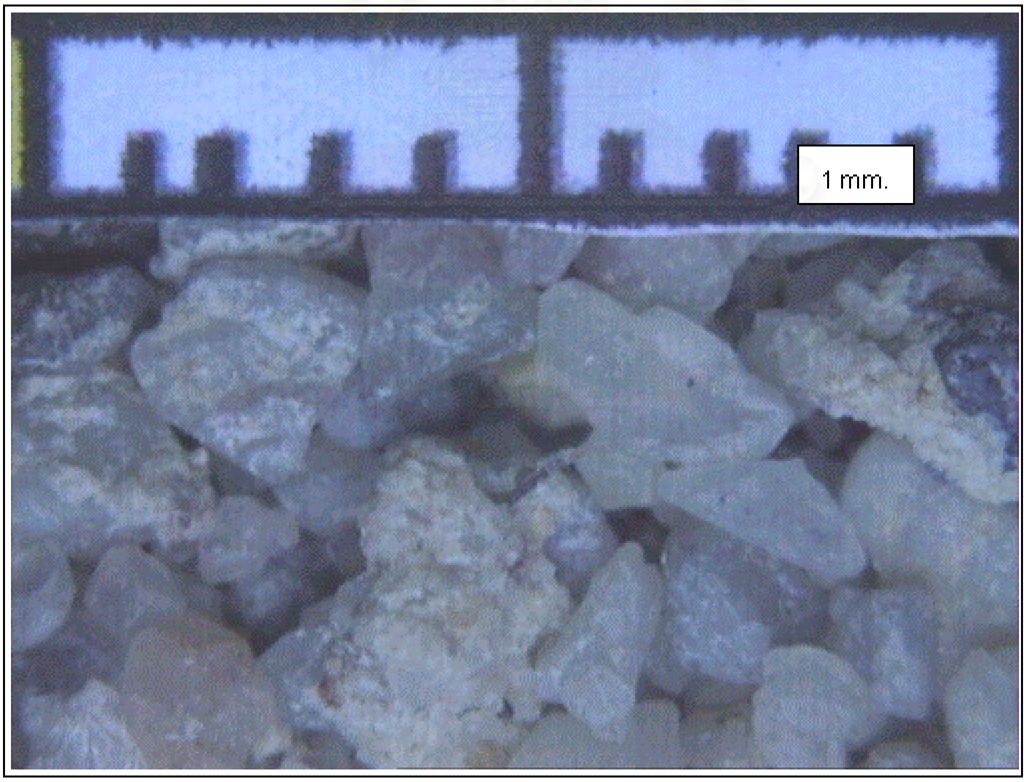

Figure 2.5 The fourth unit showed pale gray to light yellowish coarse sand

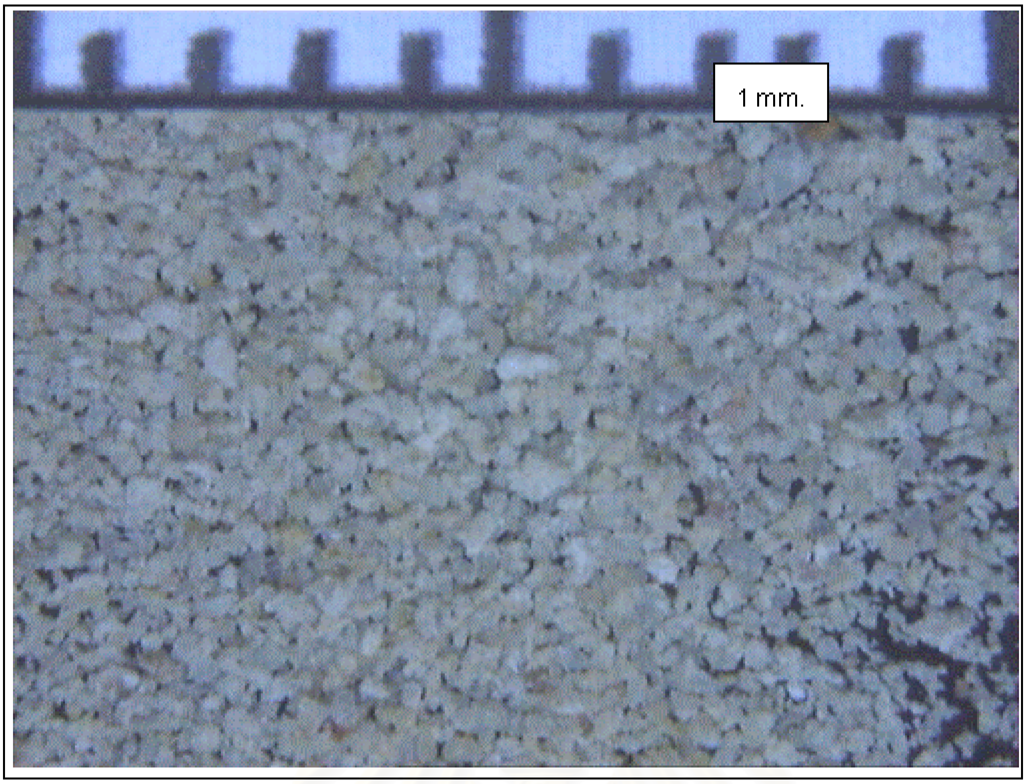

Figure 2.6 The fifth unit showed gray to yellowish gray silt clay.

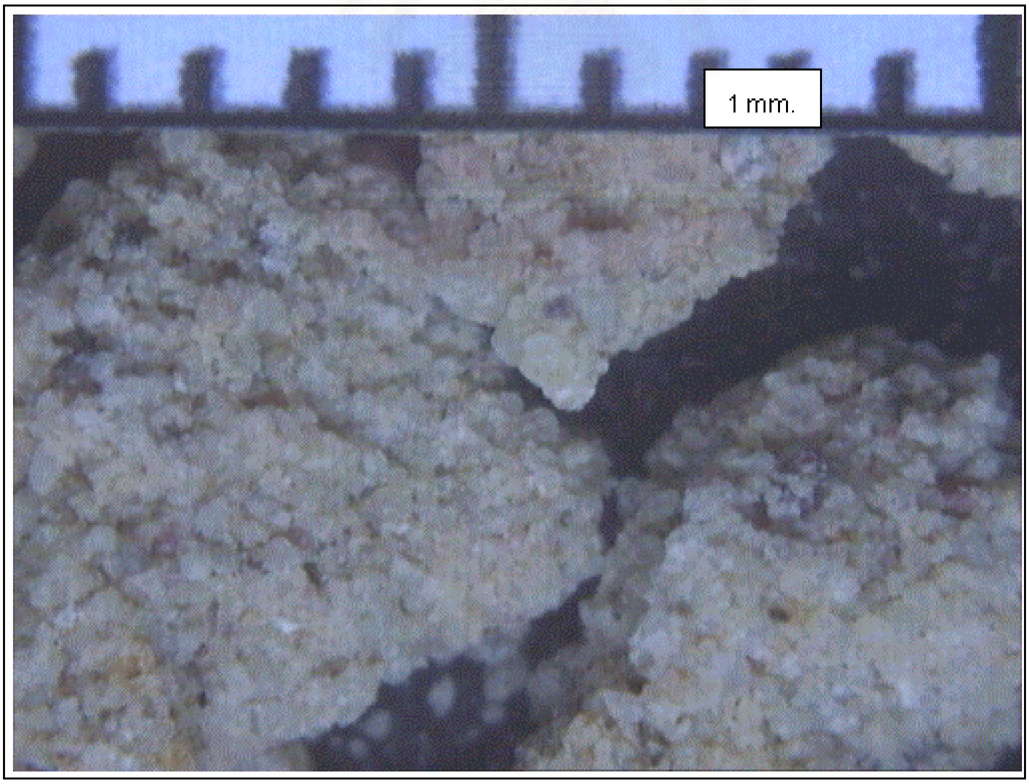

Figure 2.7 The upper most unit showed yellowish brown silty clay.

The coarse grains components are moderate to well sorted, subangular to subrounded. It composed of fine sand to very coarse sand with some pebbles included, which also shows finning upward sequence observable on cuttings (figure 1.11). This finning upward sequence is about 10 meters thick. The distinctive character of this unit is reddish brown to yellowish brown colors which can be observed on the uppermost section of every well.

From the distinguishable characteristics obtained from cuttings, the sedimentary deposits are classified into 2 formations as A and B. The observable characters of colors, compositions and sedimentary textures are the basic tools uses in this classification (figure 2.8).

2.3.1 Formation A

Formation A formed as a basement rock of the area, it composed entirely of red clay which indicated by cuttings. This red clay is consisted of silt and clay with some trace mineral of gypsum and rock salt which shown up in X-ray diffractograph (appendix VI). It appeared to cover the entire study area. The thickness of this formation can not be obtained since there was not a single well penetrated through the formation. The upper surface elevation of this formation is vary, it appeared at depth of 204 meters from surface in well No. AA 1727 that indicated 65 meters above mean sea level. The well No. DP 270, this formation appeared at 101 meters depth from surface which indicated 60 meters above mean sea level. From the figure 2.9, the red clay can be discovered in the west at shallower depth than the central of area. While, the distribution of this clay in the central area is undulated surface. The shallower on the west indicated by the borehole data especially E-logs and cuttings. Since there was not any major tectonics during and after the deposition the uneven and non-leveling surface of this formation probably due partly from paleogrographic surface and may also from some salt tectonics. The dissolution by groundwater later on play some important role followed with compaction by overburden loaded. The red color shown

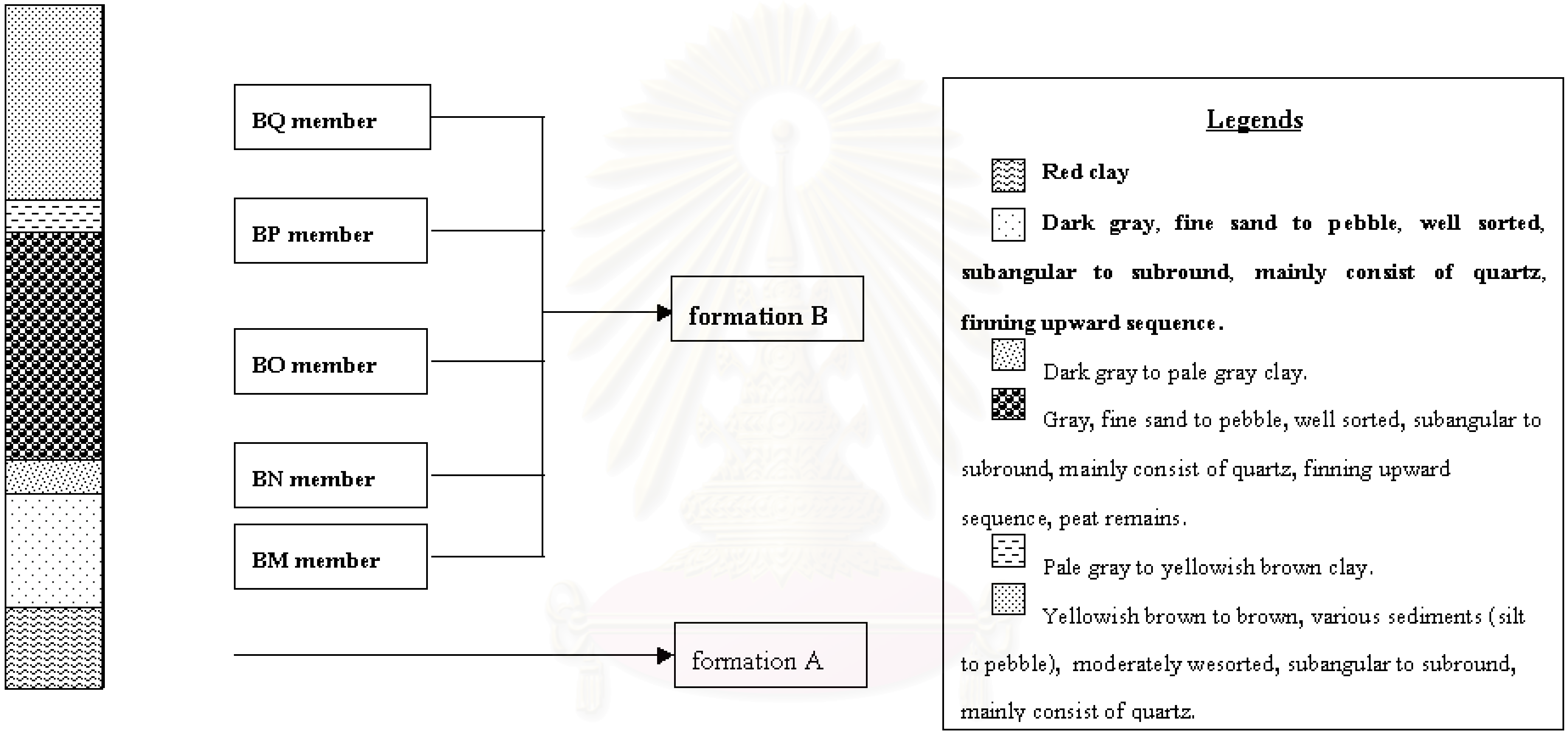

Figure 2.8 The Quaternary geology type section of the study area (not to scale).

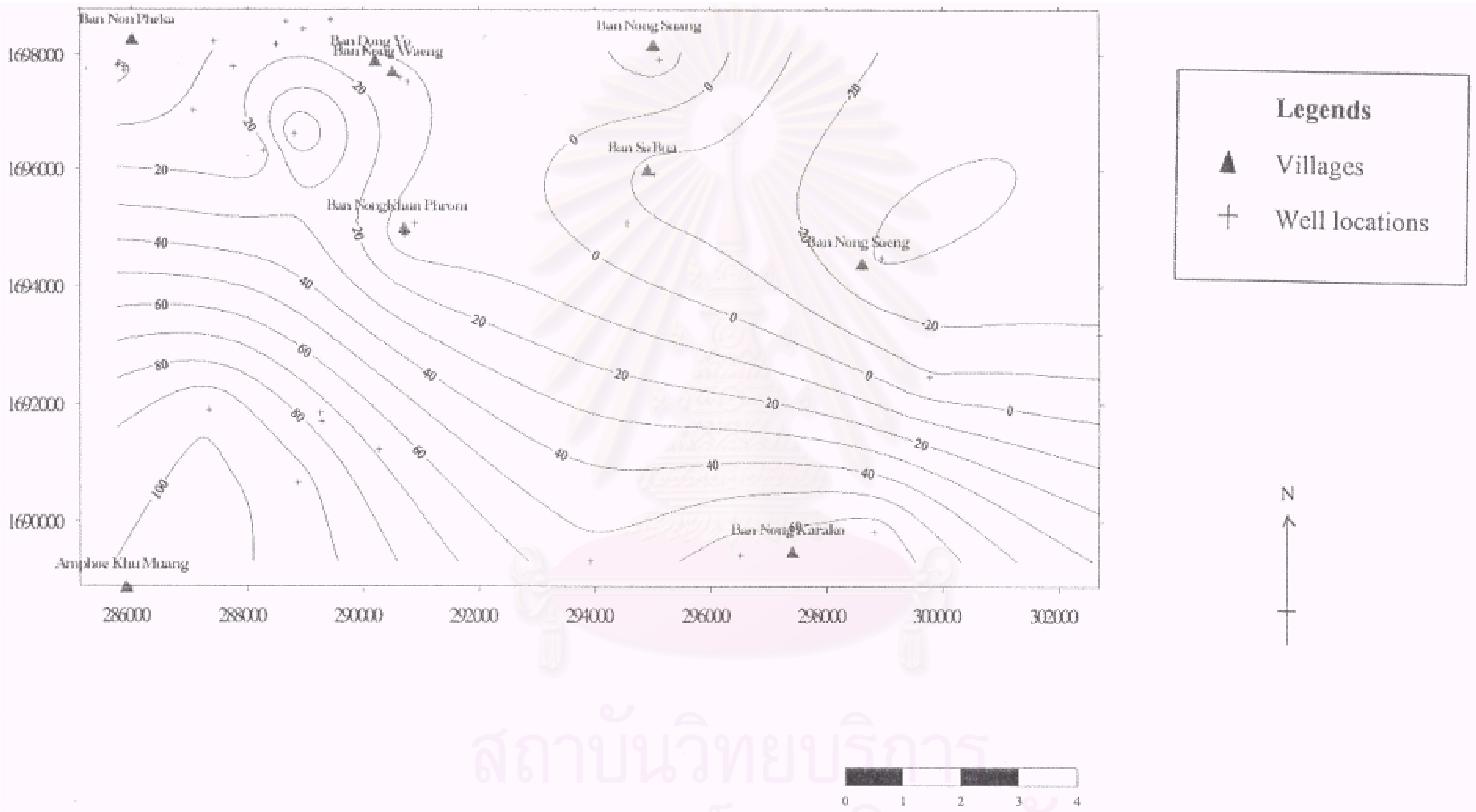

Figure 2.9 The subsurface elevation of top surface of formation A above mean sea level.

by cuttings is the typical characteristic of this formation which indicated the oxidizing environment of deposition. Most of the cuttings samples from this formation are of silt and clays size with some very fine laminae which pointed to lacustrine environment of deposition.

The formation would be syn-deposited with rock salt which the crystalline salt were partially adopted into the formation during deposition. The contamination of the overlying aquifers could have been caused by some dissolved salt from this formation dispersed or leaked into the used to be fresh groundwater.

The E-log patterns of this formation show both typical characteristics of SP and resistivity logs (figure 2.10). The signature of SP log is moved closed to the shale line indicated the lithology and the signature of resistivity log referred to low resistivity of saltiness. This formation is underlained unconformably the formation B. The indices to indicate the boundary between this two formations is the color which changed abruptly due to the changing of their environments of deposition.

2.3.2 Formation B

The sedimentary deposits of formation B is laid down unconformably on top of formation A which formed as an eroded basement. The color of formation B is gradually changed from dark gray on bottom layers to yellowish brown on top layers. The characteristic of sediments in this formation is quite obviously different from the formation underlain. This formation is deposited as a thick sequences of fluviatile environments which running almost parallel with the present day Mae Nam Mun. This formation B can be subdivided into 5 members as BM, BN, BO, BP, and BQ members. The division of each member is based on the changing of lithological contents and colors which probably reflected from their changing environment of deposition.

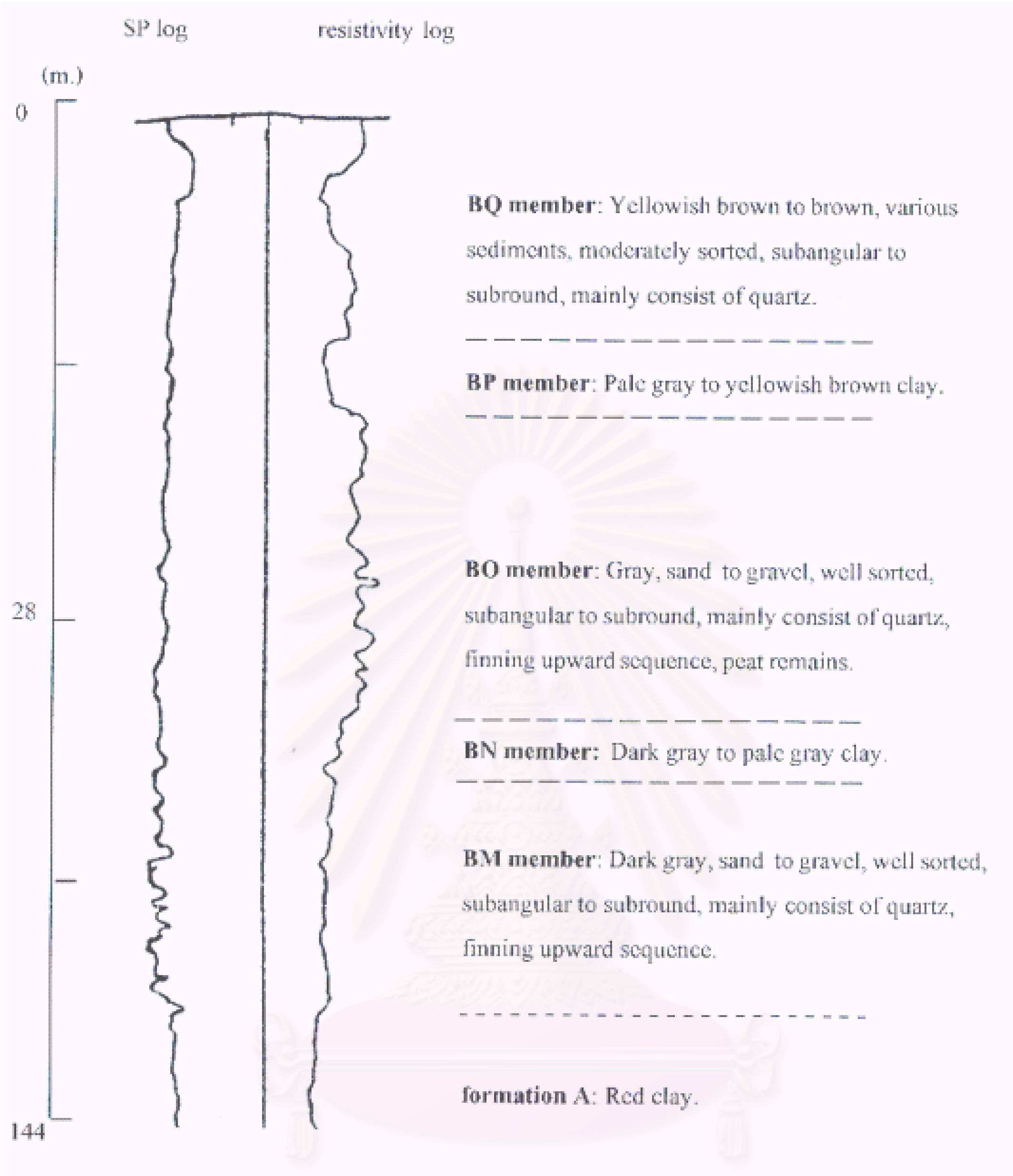

Figure 2.10 The well No. RTA 16 that shows the typical electric logs pattern of this study area.

2.3.2.1 BM Member

The BM member is the first member of the formation B which overlain unconformably on top of formation A (figure 2.11). The distinct characteristic that used to separate this member from the formation A is their colors which is red for formation A and dark gray of member BM. This member consisted of two type of sedimentary layers as sand and clay layers. The dark gray clay bed is laid down on top of formation A and underlain sand bed. This clay bed usually found spread around Ban Nong Saeng and does not appeared further down south. The average thickness of this clay bed is 50 meters. The top sand bed of BM member composed of sand of various sizes from very fine to coarse sand with some pebbles included. The color of sand is dark gray like clays underneath which used as an indices to separate this member from the preceding one. The sedimentary character of BM member shows subangular to subrounded and well sorted. The surface of this member appeared shallower to the surface and higher subsurface elevation to the south than to the north. The subsurface structure between Ban Nong Karako and Ban Nong Saeng appeared to posses a steep slope. Beneath and on top of member BM, evidences derived from cuttings suggested the environment of deposition would be lacustrine for clay and fluviatile for sand layers. And the deposition is also a syn-deposit as sedimentation would be together with the dissolution of some salt content of formation A underneath the deposition. The more salt dissolved will increased more space for further sediments to be collected. The continuation of this process will enable the area to collect thick clay layer which do not spread much as it appeared to be confined around Ban Nong Saeng. The later sand collection which laid down on top of this thick clays shows much greater areal extension. This sand layers consisted of sand of various size from fine sand to granules. The finning upward sequences of coarse to fine sand which indicated the fluviatile environment of point bar deposition. The average thickness of this sand layer is 30 meters while the thickest section is found at Ban Nong Saeng from well No. 1726 at 78 meters (figure 2.12). The sand is composed of moderately well sorted

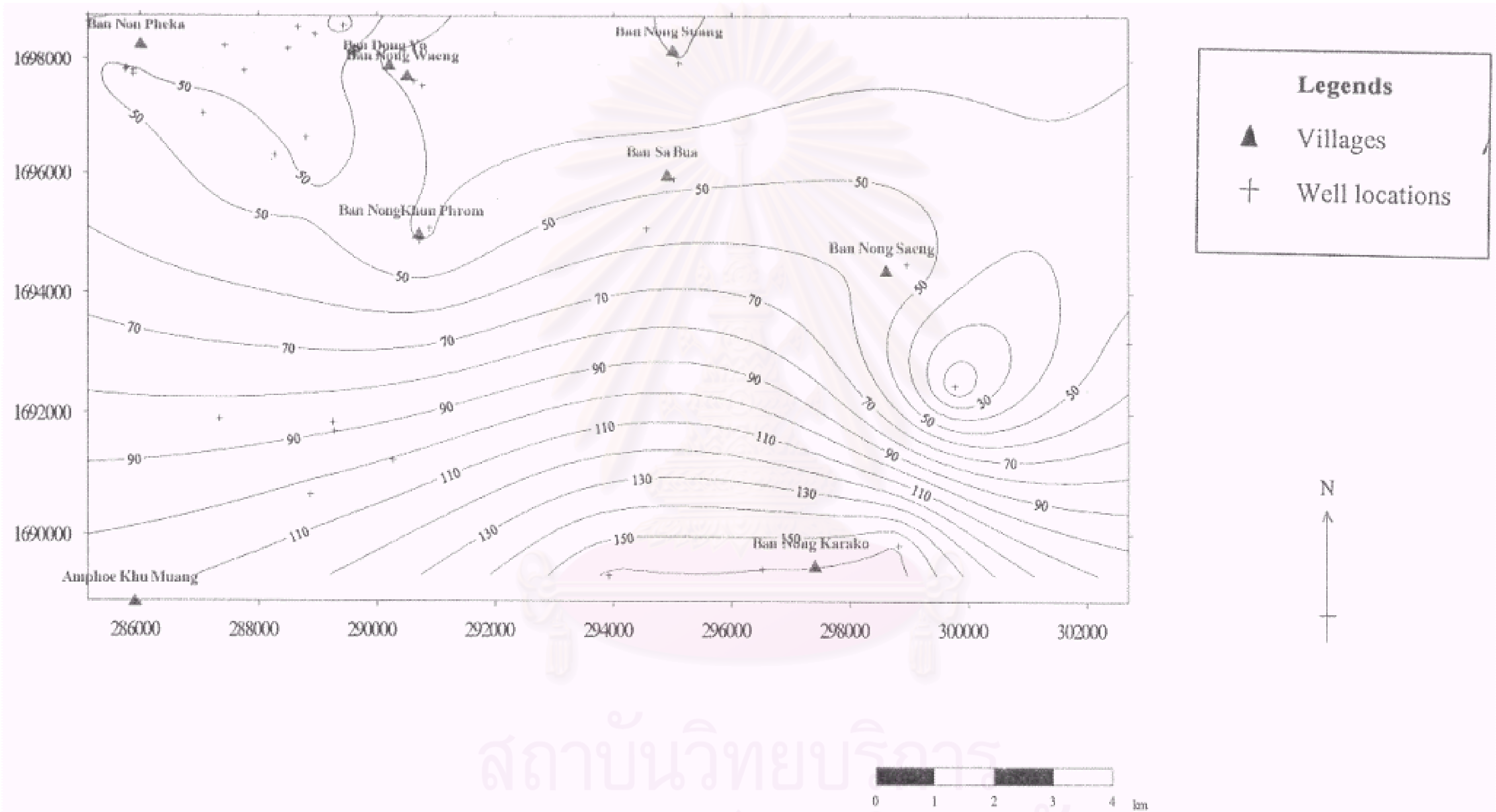

Figure 2.11 The subsurface elevation of top surface of member BM above mean sea level.

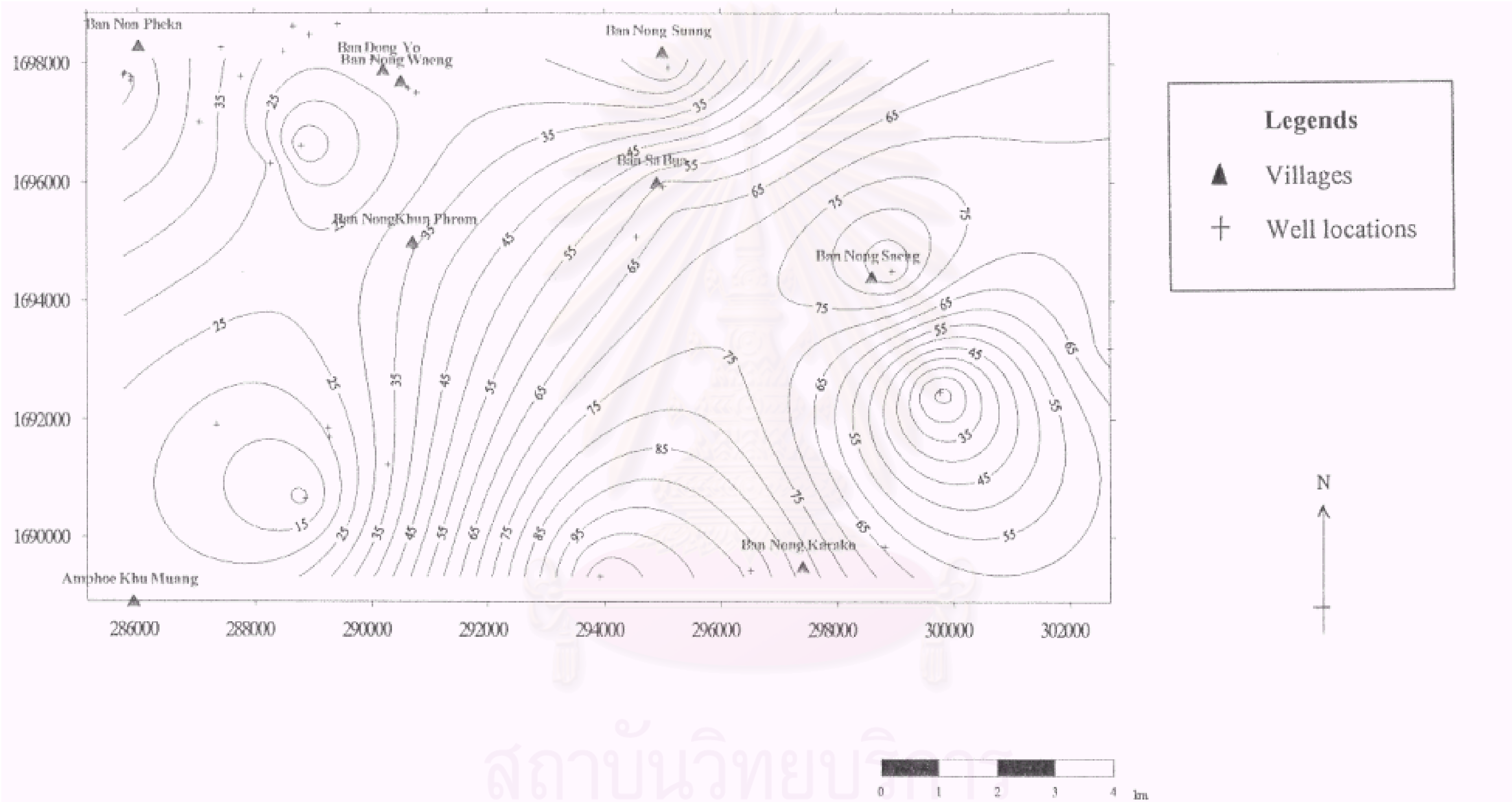

Figure 2.12 The thickness of member BM (m.).

quartz sand with little of chert, jasper, and some rock fragments of yellowish gray fine-grained sandstone.

The E-log pattern of this member appeared with some distinct signatures which can be used in separation from the formation A. The typical signature of SP log appeared close to the sand line which indicated high sand contents, while resistivity log signature moved from low resistivity region of formation A to a higher resistivity of member BM.

2.3.2.2 BN Member

Next member is BN member which lainover the BM member. The distinct characteristic of BN member is thick clay bed that laid down on top of member BM(figure 2.13). The subsurface elevation on top of BN member does show a steeply dipping angle to the north on the southeast corner between Ban Nong Saeng and Ban Nong Karako while on the south west corner the same surface shows gently dipping angle to the north. The average thickness is 5 meters (figure 2.14) and thickness of this member is not uniform, it's thick beds appeared on the north and thinning to the south. It laid down conformably with the BM member. The color of this clay bed is quite uniform and gradually changes from dark gray to pale gray to the top. The composition is mainly composed of quartz (x-ray diffraction, appendix VI). This member is widely extended to cover the study area except the southern part. It is the impermeable bed that traps the BM aquifer to be confining aquifer. The deposition environment would be lacustrine deposit because most sediments is silty clay and the thickness is not uniform.

The e-logs pattern of this member is quite distinctive in the resistivity log. It showed the low resistivity in this depth. In SP log, it does not appear to have any distinguishable signature on BM member to confirm.

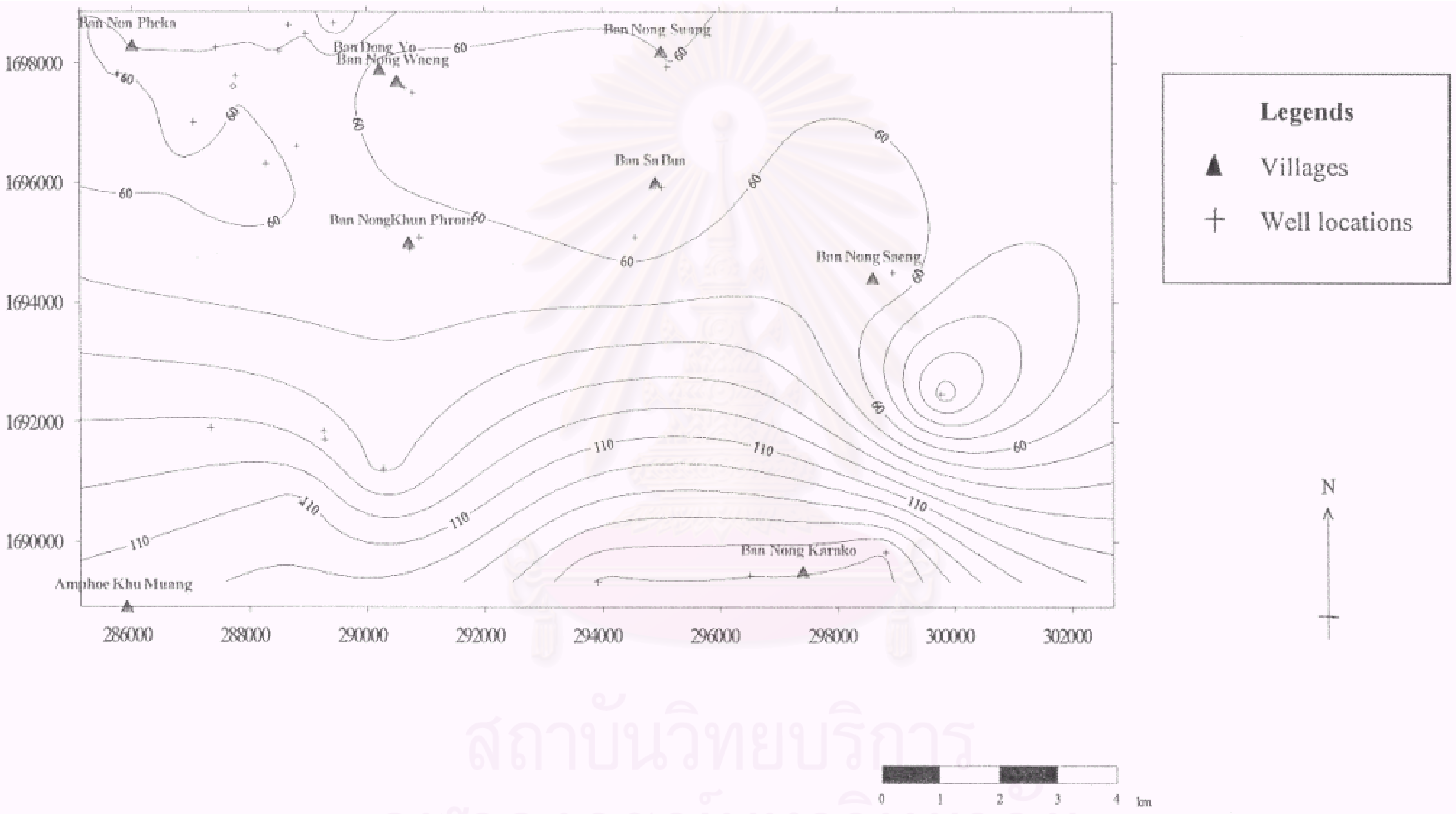

Figure 2.13 The subsurface elevation of top surface of member BN above mean sea level (m.).

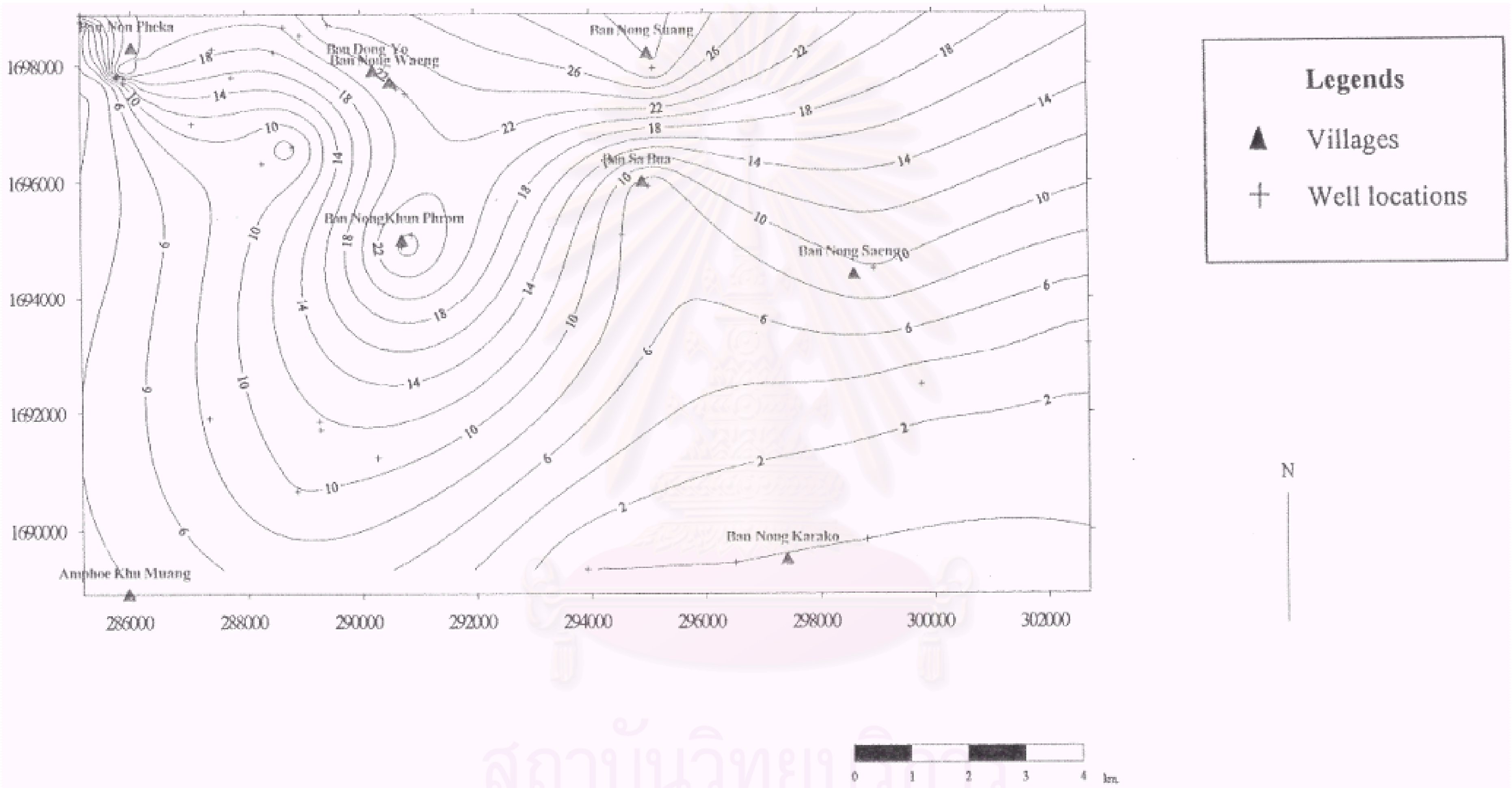

Figure 2.14 The thickness of member BN (m.).

2.3.2.3 BO Member

The next member which laid down on top of member BN is BO member. It is separated from the underneath member by color and size of sediment. The color is gray to pale gray. The size of sediment is changing from silty clay to coarse-fine sand. The main composition is quartz and some trace of chert, jasper, and rock fragments. In some well at Ban Non Phaeka, it can be found pieces of peat. The typical sedimentary structure is finning upward sequence. The thickness of the point-bar sequence is about 10 meters. The subsurface elevation of this member gradually decrease from south to north, at approximately 150 meters to 80 meters above mean sea level (figure 2.15). The thickness is thickening in the central area that extends along east-west direction (figure 2.16). The thickness in this part is about 50 meters. The thickest section found in RTB 34 B9 situated between Ban Nong Saeng and Ban Nong Karako.

The E-log appeared with some typical patterns in the resistivity log. The high resistivity signature appeared on log made the separation and correlation possible from central to the north. The E-log patterns appeared differently down south which made correlation with E-log to the south not possible.

The depositional pattern of this member can be interpreted as fluviatile depositional system. The thick body of sedimentary deposits is laid down along the flowing channel. The finning upward sequence can be referred to the point bar deposit.

2.3.2.4 BP Member

Next is BP member which laid to overlain BO member. The distinct character is pale gray to yellowish brown silty clay. The main composition is quartz. The subsurface elevation is gradually decrease from southern to northern, and from 150 meters to 100 meters above mean sea level (figure 2.17). The thickest body of this member can be found at Ban Dong Yo, northern part of area and gradually thinning out to the east, west, and south (figure 2.18).

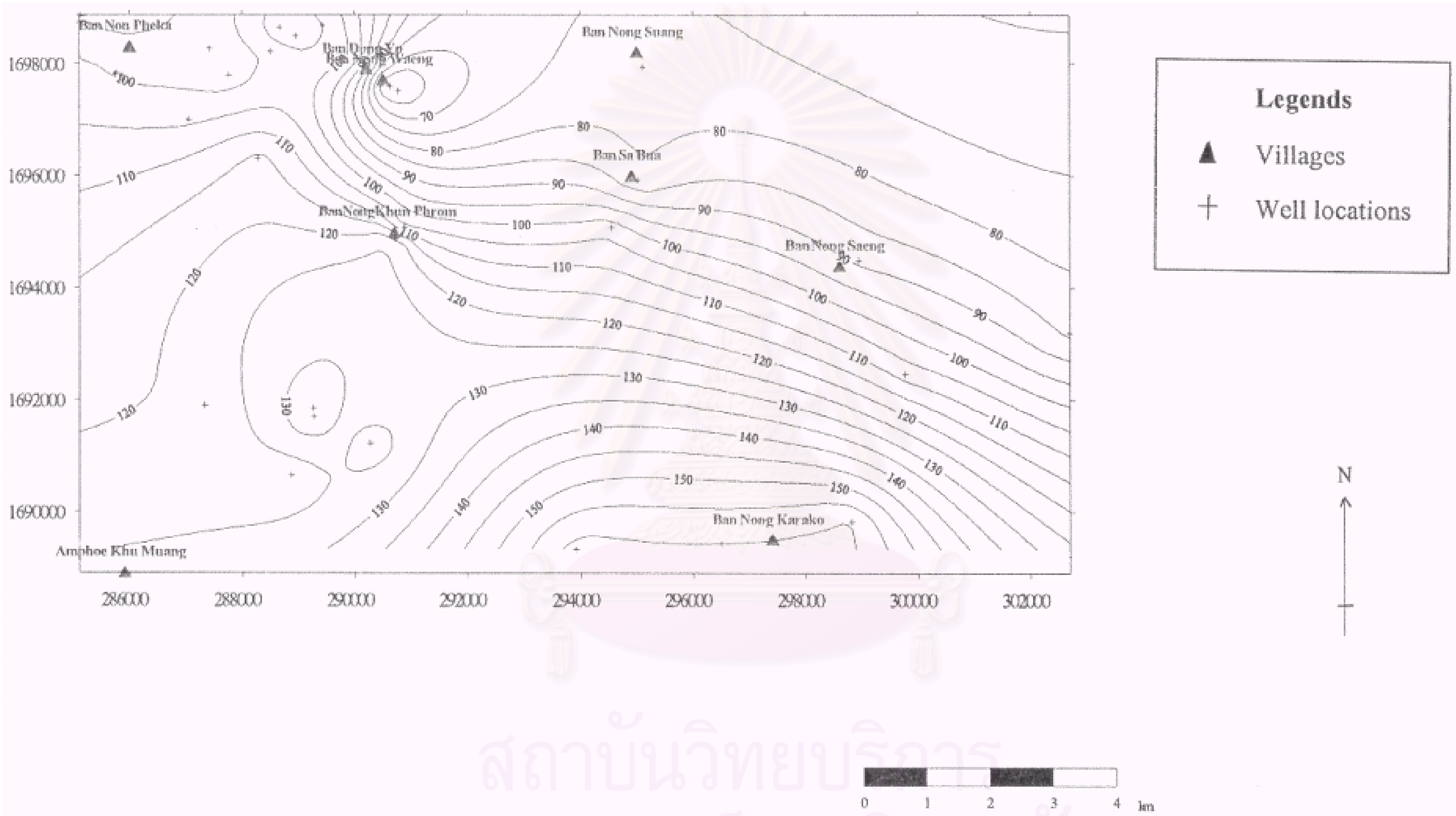

Figure 2.15 The subsurface elevation of top surface of member BO above mean sea level (m.).

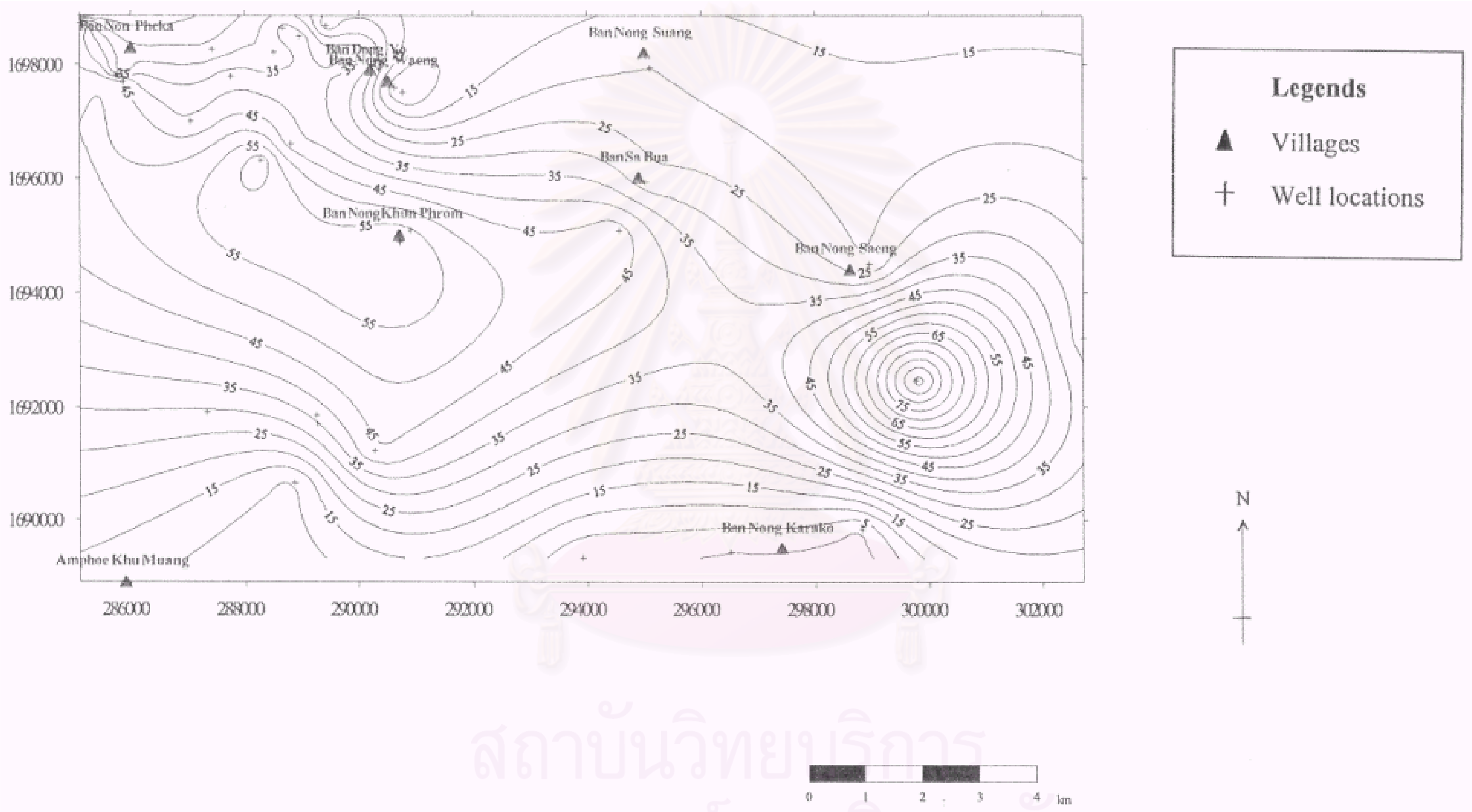

Figure 2.16 The thickness of member BO (m.).

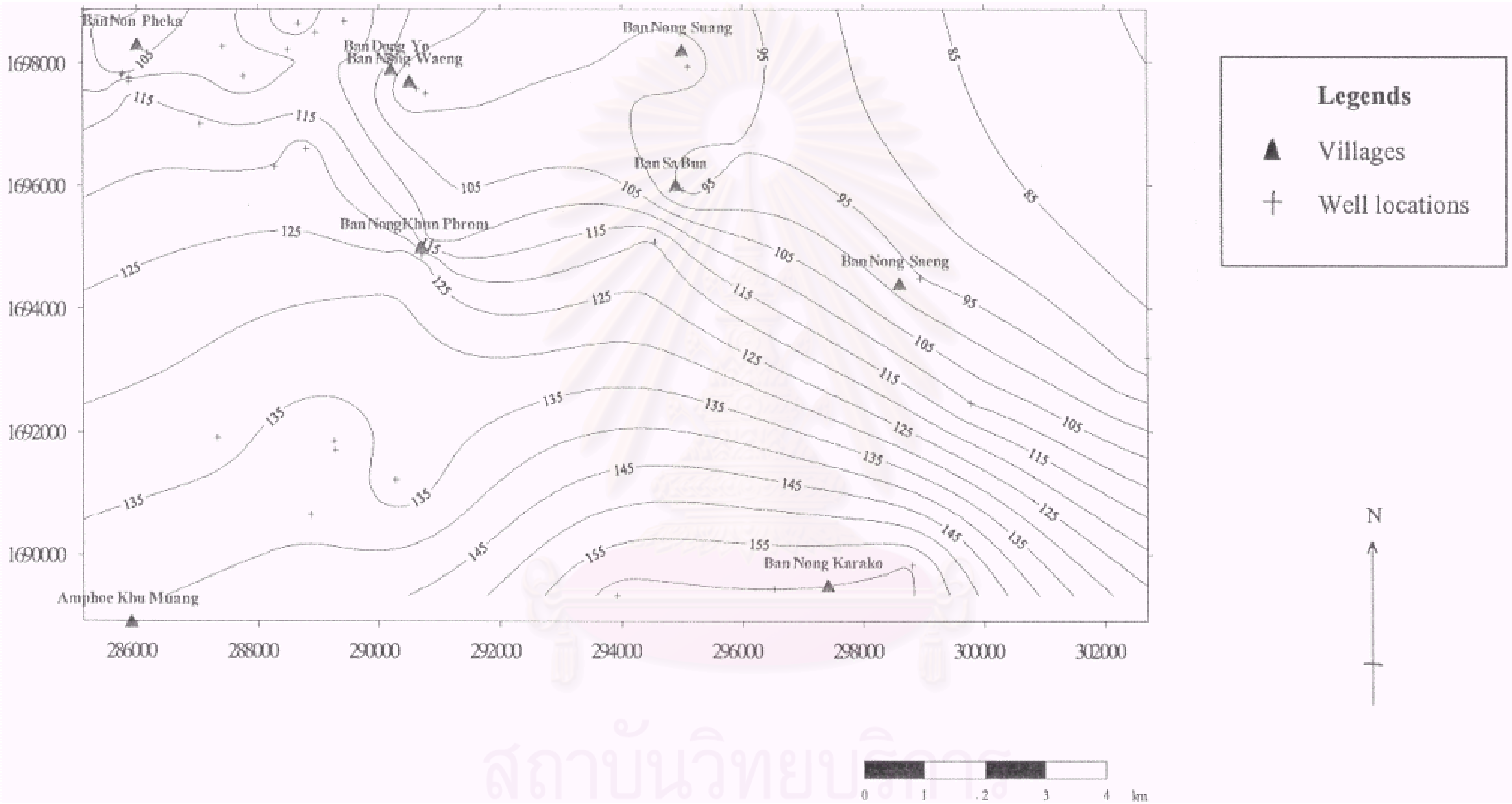

Figure 2.17 The subsurface elevation of top surface of member BP above mean sea level (m.).

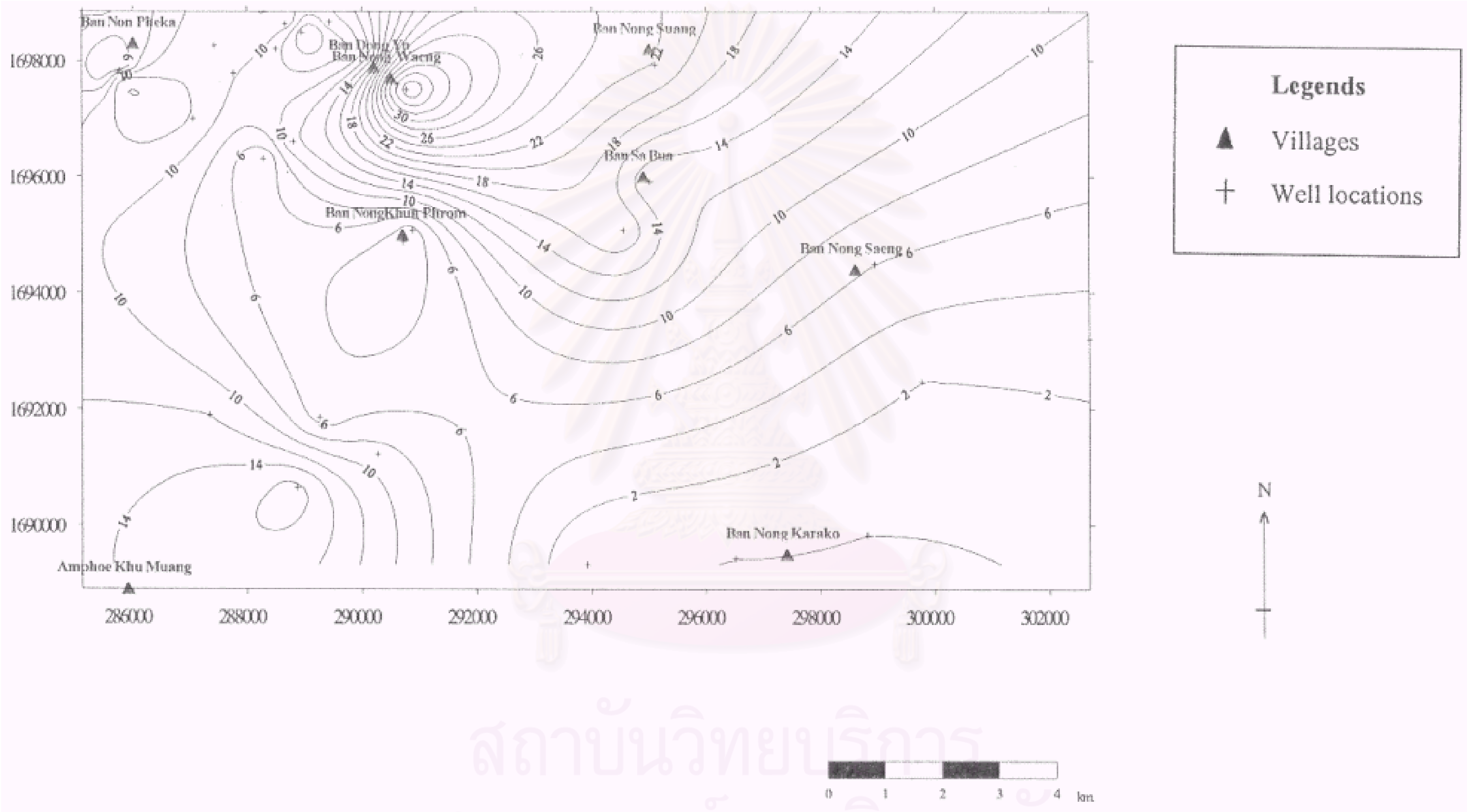

Figure 2.18 The thickness of member BP (m.).

The E-log pattern of this member is obviously changed in resistivity from high resistivity to low resistivity but it is difficult for well to well correlation in the south and east, since the typical low resistivity pattern do not show up there.

The laid down pattern of this member can be referred to lacustrine deposit. The sedimentary deposits are composed mainly of silty clay and it is gradually thinning from the north to the south.

2.3.2.5 BQ Member

The upper most member is BQ member. This member can be differentiated from BP member by its reddish brown to yellowish brown color and various types of sediments which comprised to the recent alluvial deposit that laid over the BP member. The main composition is quartz with traces of chert, jasper, rock fragments, and latterite. The typical character of sediment is shown as finning upward sequence. The thickness of this member is about 35 meters in the north and thinning to the south, about 10 meters (figure 2.19).

The E-log pattern can be separated from the BP member by the changing of signature from low resistivity to high resistivity.

The depositional pattern can be interpreted as the recent alluvial deposit along the Mae Num Mun.

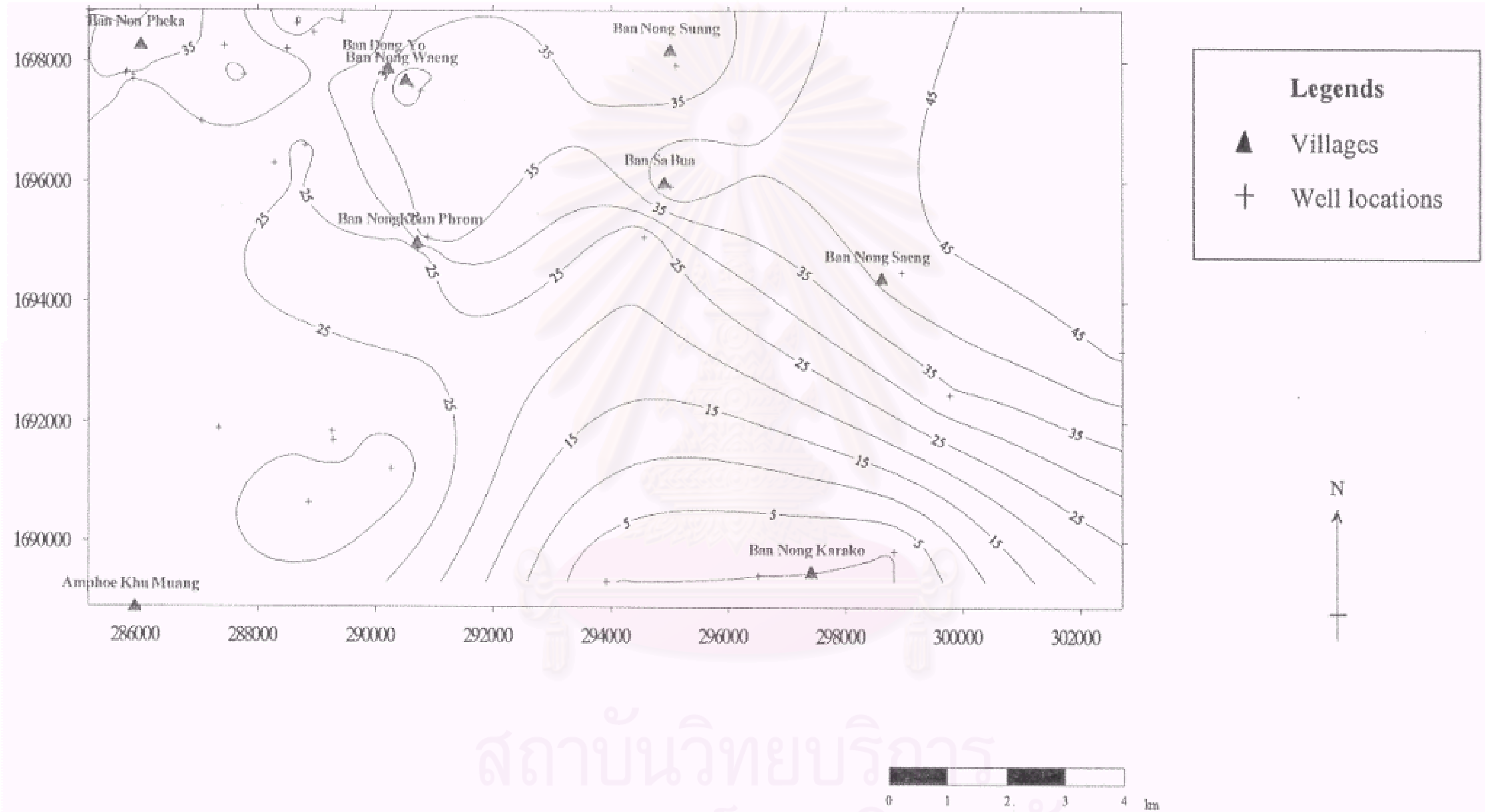

Figure 2.19 The thickness of member BQ (m.).

2.4 Stratigraphic cross section

There are 4 lines of stratigraphic cross section that illustrated across from north to south direction in this area (figure 2.20). The first line of cross section is A-A' line in the western part of study area (figure 2.21). There are the subsurface elevation of each formation above mean sea level, the thickness and the e-logs character of the well No. RTA 15 and MG 1462. The subsurface elevation of formation A decrease from south to north. This formation can not be estimated the thickness. The overlain beds are BM member. It is the thick sand to gravel sedimentary beds that extended from north to south. The thickest of this member is illustrated in the north and thinner to the south. The overlain bed is BN member that is the silty clay bed. This bed is thin bed that extended from north to central part rather near the southern part of area. Then, this bed is disappeared in the south. This bed is separated the BO member from the BM member. The BO member is the sand to gravel sedimentary beds same as the BM member. This member is extended and conformed with the BM member from north to south. The thickest of this member is illustrated in the central part and gradually thin out to north and south directions. This member is lain under the BP member that mainly consisted of silty clay the same as the BN member. The BP member is extended throughout the study area.

The second line is B-B' (figure 2.22). This cross section is illustrated likely the section A-A'. There are the e-logs of well No. CC 1673, MG 1460 and MG 1461. In this cross section, it is far from the first section to the east direction about 4 kilometers. There is a mound shape structure appeared in A formation at the northern part. This would be resulted from its low salt content in this part of the formation. The less dissolution in this part will be left with thick remnant in this area. It can be observed the changing of the thickness of the B formation in this cross-section comparing with the previous section. The BM formation is thinner in this section but the other members are thicker than the former section. In BO member, the thickest part is showed in the central part of cross section.

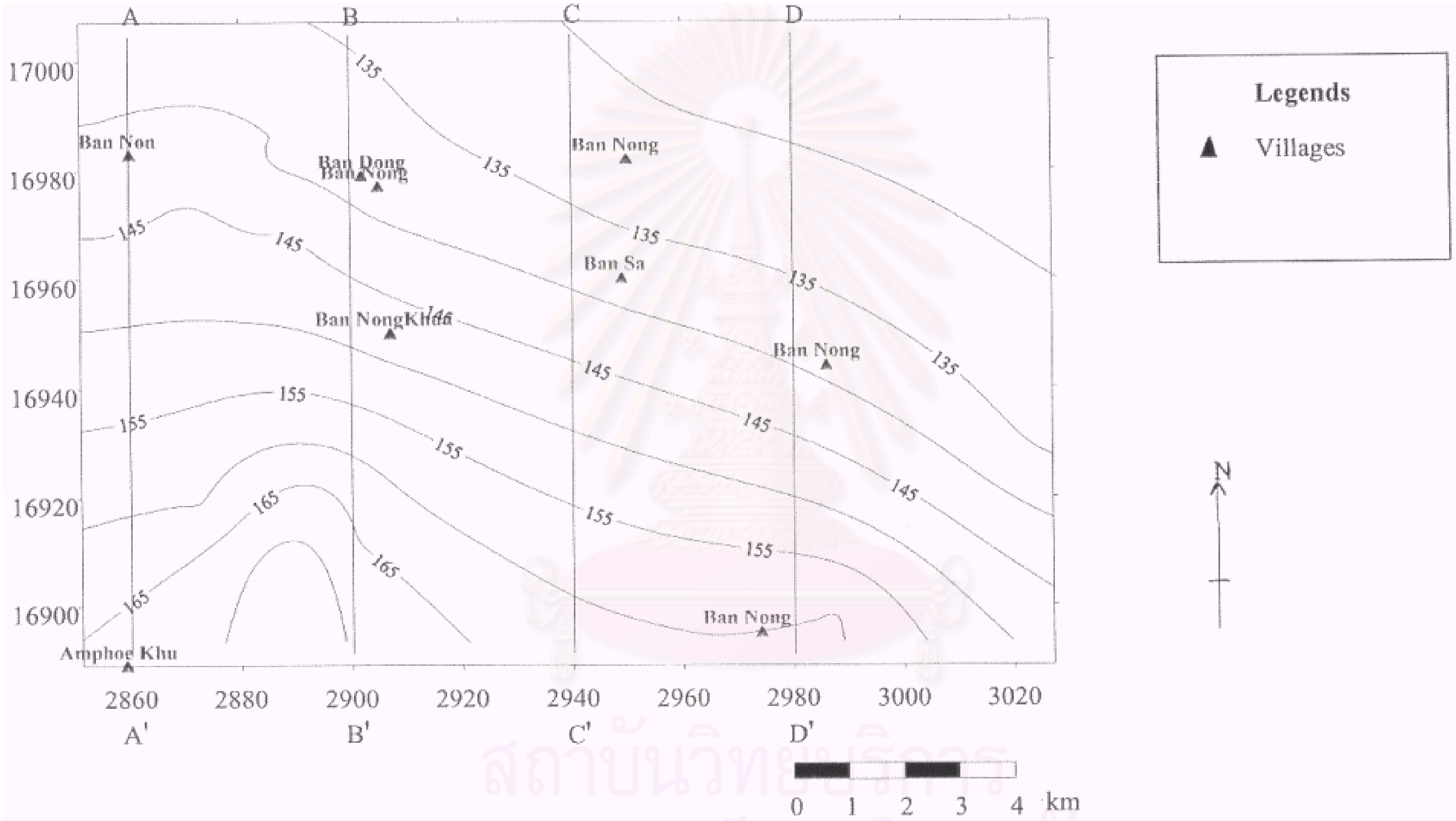

Figure 2.20 The lines of schematic cross sections of the study area.

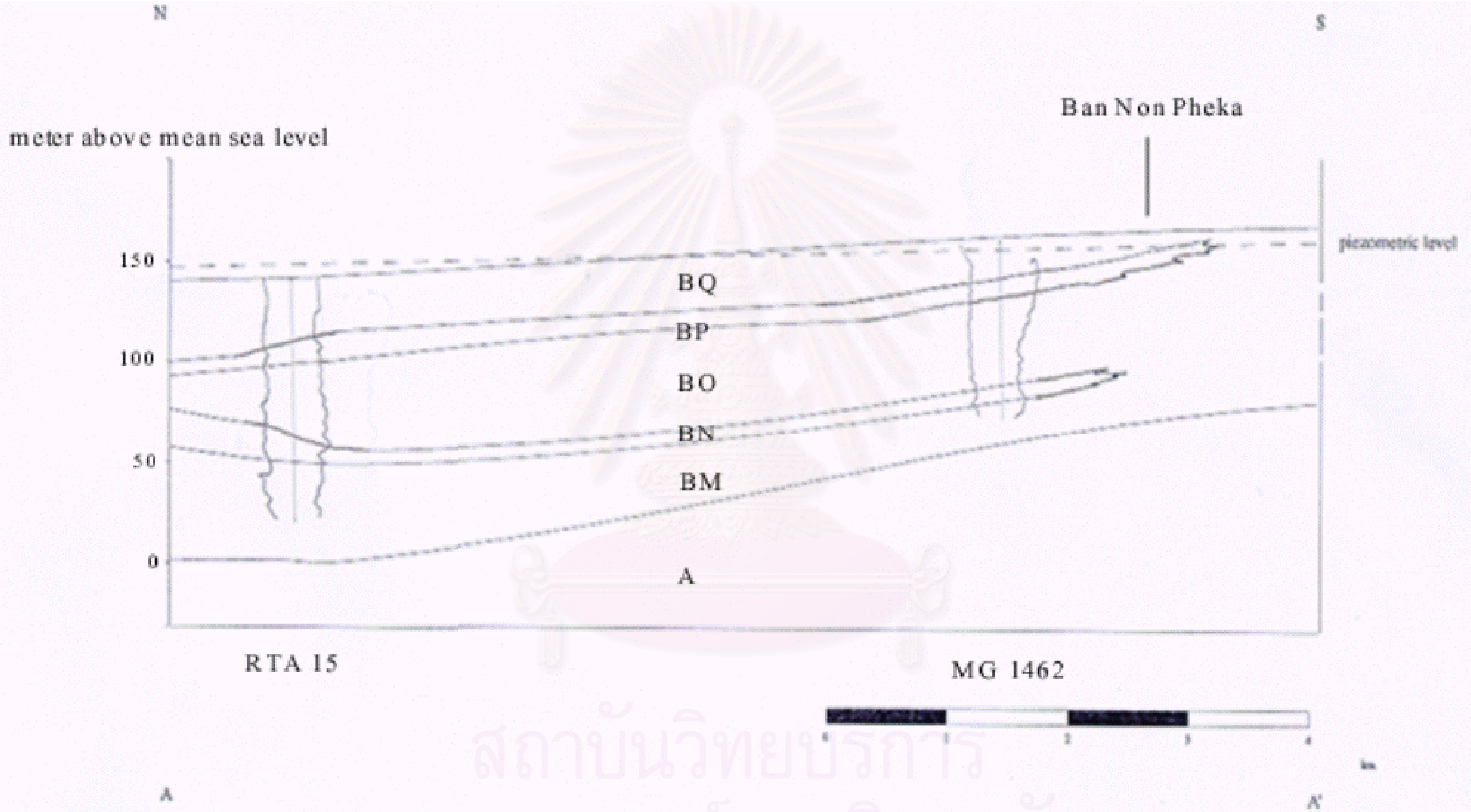

Figure 2.21 The schematic cross section of A-A'.

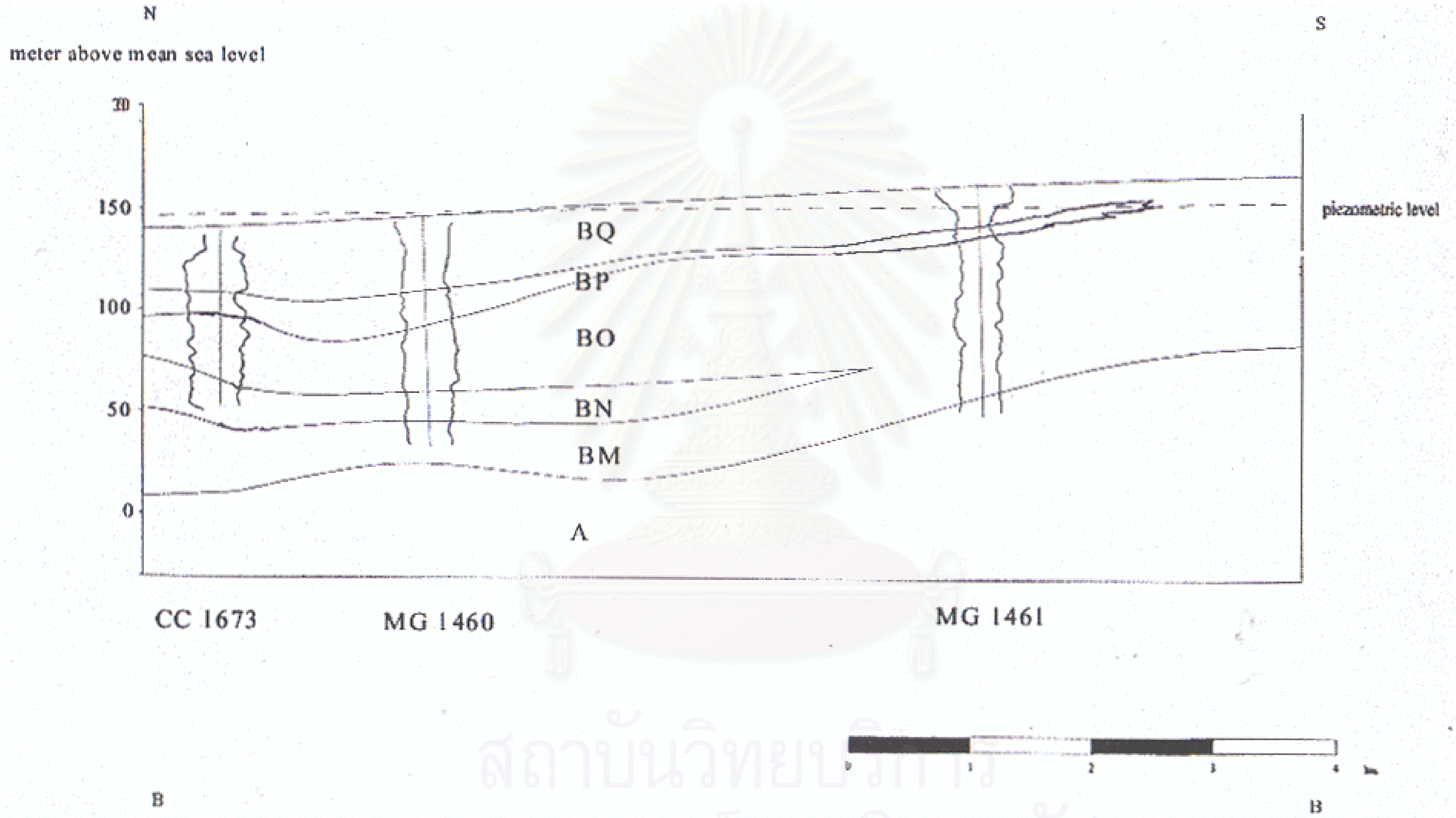

Figure 2.22 The schematic cross section of B-B'.

The third line is C-C’ (figure 2.23). This section is far from the former section about 4 kilometers to the east direction, too. There are 3 e-logs as No. RTA 15, MK 1507 and L 1733. In this cross section, the thickness of BM member is changed. It is thicker in the southern part and thin out to the north, and BO member is appeared be thinner than the section B-B’. Both are composed of silty clay sediments, BN and BP members are thick in the north and thin out in the south.

The fourth line is D-D’ that further to the east direction about 4 kilometers (figure 2.24). There are e-logs No. L 1735 and L 1733 in this section. The subsurface elevation of formation A is decrease from south to the central of area and gradually increases to the north. The significant of this cross section is the thick body of BM member along north-south direction. This phenomena probably came from the dissolved of the high salt content in the A formation to form a deeper depression than the other part of this area. The BO member is thick in the south and thin out to the north. Both silty clay, BN and BP members are thick beds in the north and gradually thinning to the south.

Conclusion

The Quaternary stratigraphy of this area can be divided into 2 formations. The lower formation is A formation that lies throughout the area. The typical character is red color. The subsurface elevation is high at the southern part and the elevation decreases to the north. Except the west direction of the northern part, it apperedas a mound structure. This would be reflected to its originally of low salt content that led to less dissolved and left with thick remnant. The upper formation is B formation, it consisted of 5 members separated by using the characteristic of the sediment itself. The sequence from bottom to top as BM, BN, BO, BP and BQ. The BM and BO member are thick beds of sand to gravel size sediment and showed the finning upward sequence. They are extended throughout the area. The other, BN and BP member are thin beds of silty clay. These beds are extended from north to central part and disappeared in the south. The environment of depositiond of B formation is fluvio-lacustrine environment.

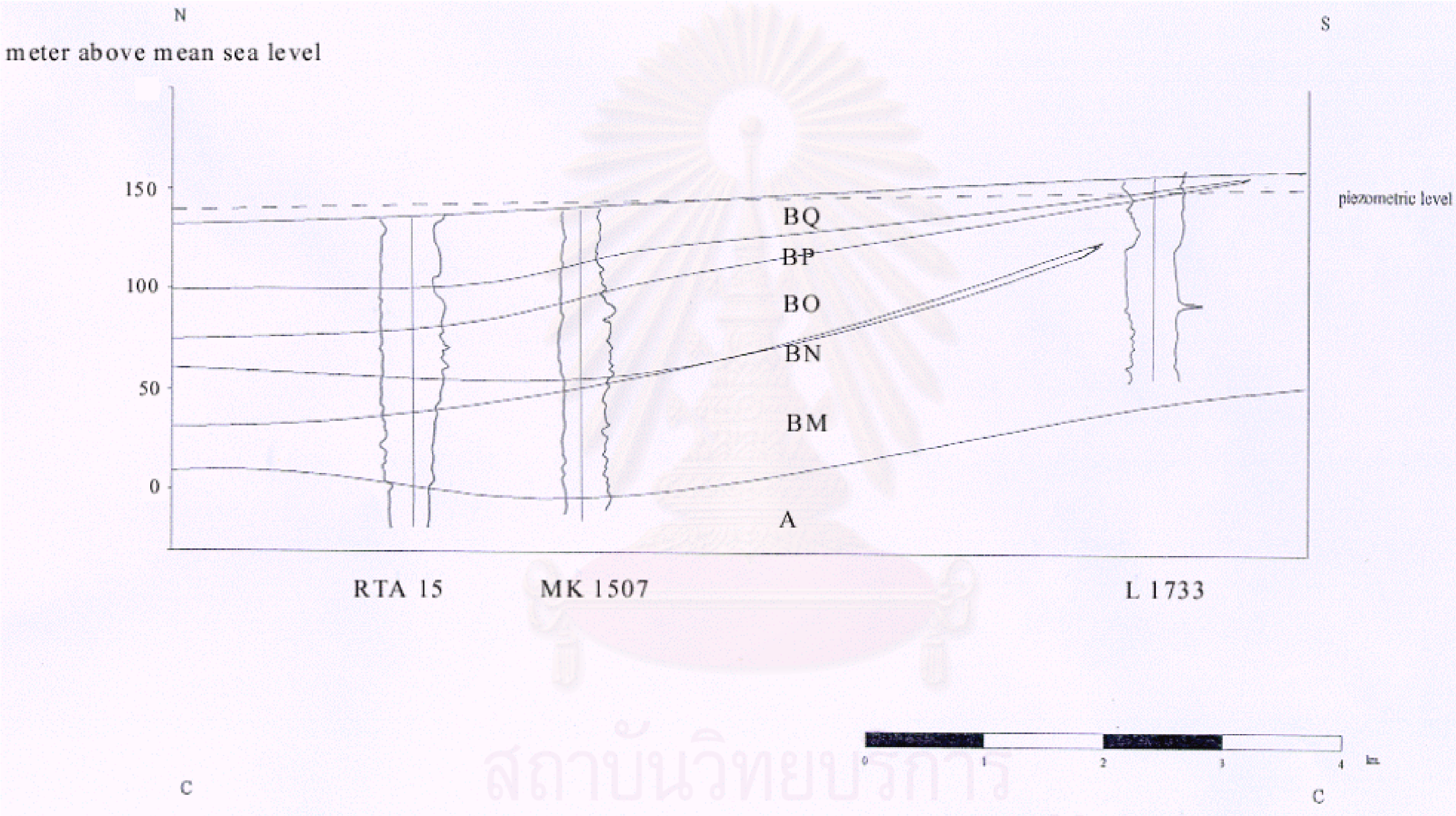

Figure 2.23 The schematic cross section of C-C'.

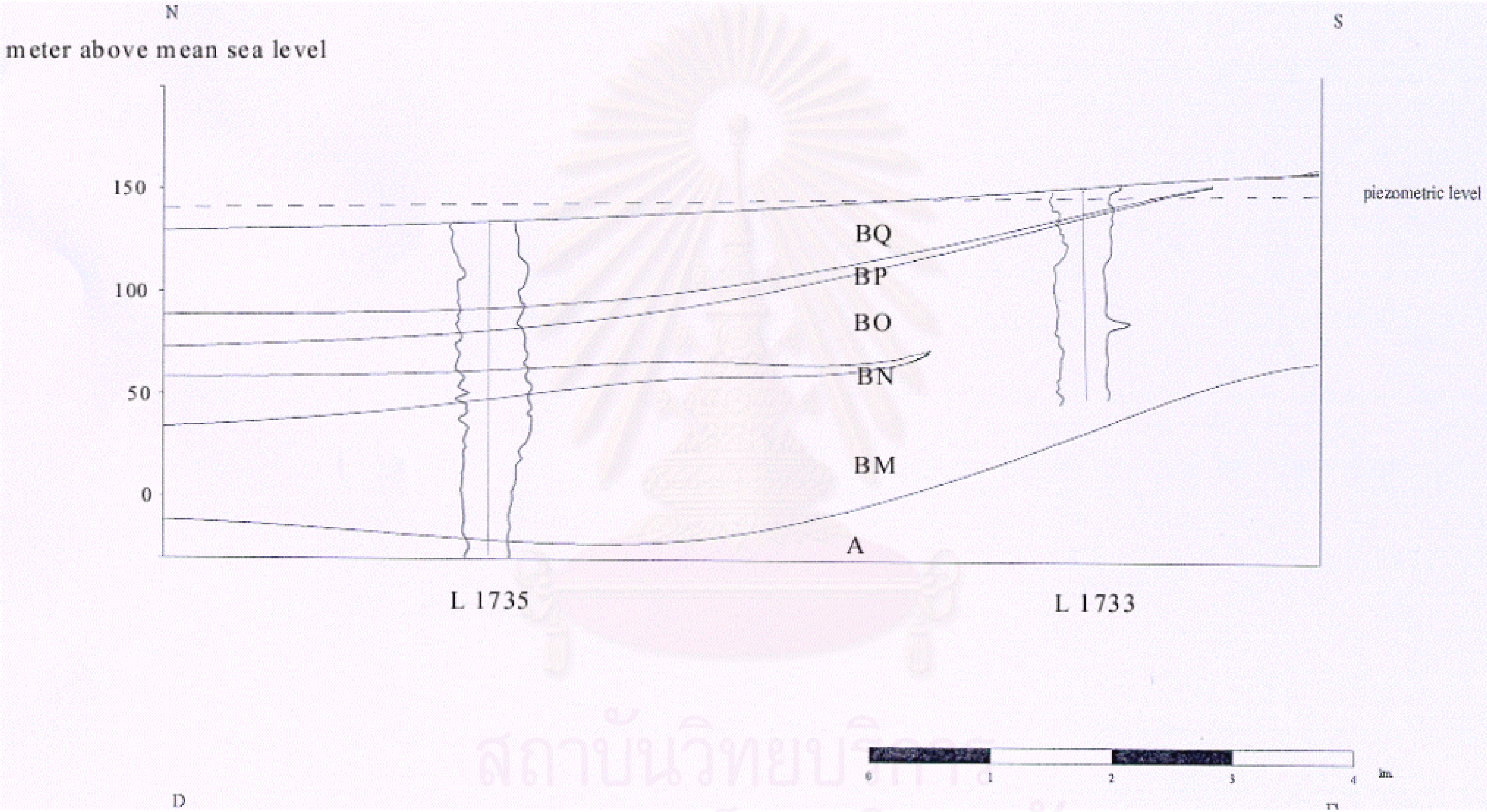

Figure 2.24 The schematic cross section of D-D'.

Chapter III

Hydrogeology

3.1 Hydrogeology

The hydrogeology of this study area is based on the stratigraphic data, the pumping test data and the water quality data are used to explain the extension of groundwater and the aquifer model. The stratigraphic data that mentioned in the chapter II can be implied to an ability to store and transmit water of 2 types as aquifer and aquitard. The aquifer is a rock with water-barring portions. The aquitard is described as the stores water that can also transmits enough water to be significant in the study of the regional migration of groundwater but not enough water to supply individual wells.

From the stratigraphic column in chapter II (figure 3.1), the formation A is the basement of this area that mainly consisted of red color silty clay. The property of this silty clay is aquitard because it does not posses enough water to supply individual well. This is the same property of BN member and BP member. They are unconsolidated silty clay that showed the typical property of aquitard character. The distribution of the formation A is illustrated in the cross section in chapter II. It can be found throughout the investigated area and the elevation is decreased from south to north. The significant of this formation is the salt that derived as secondary deposit from the rock salt in a part of the Khorat Plateau. It is the source of brackish water that found in the northern part of the area.

The BN member has the same sedimentary characteristic as formation A. It is laid extended from the north to central part of area, then it disappeared in southern part. This member is a aquitard that separated both aquifer to be lower and upper aquifer. But this aquitard is not unique because it does not extend throughout the study area. The upper most aquitard is BP member that is the significant aquitard. It

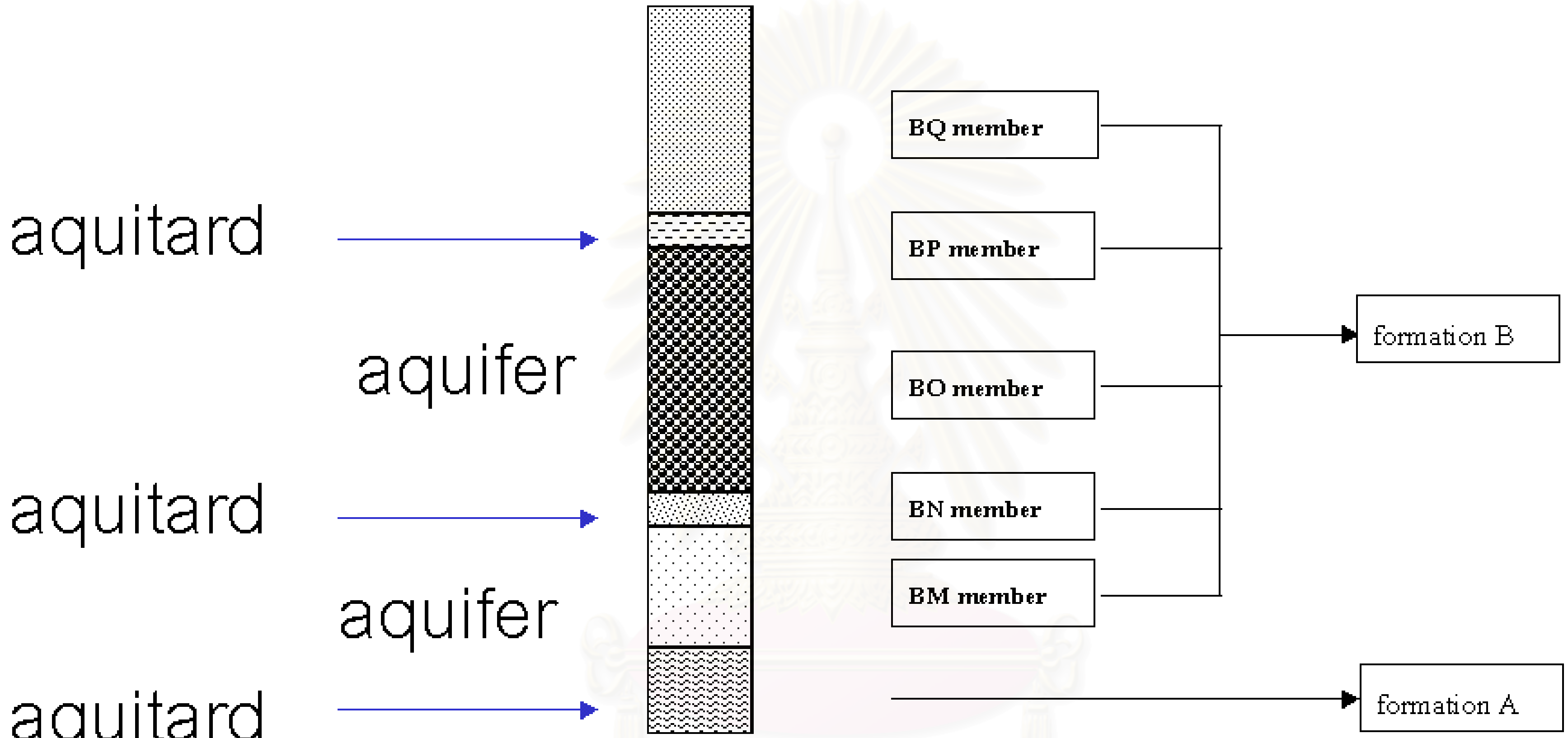

Figure 3.1 The relation of Quaternary geology and hydrogeology.

possesses the same characteristic as BN member but different only in color. It is the whole bed that trapped and raised groundwater level to be an artesian flowing well in the northern part. This member is extended from north to south of area.

The BM and BO member are aquifers that laid down interbedded with the aquitards and confined by the BP member. The characteristic of sediment in the BM member is sand to pebbles size grains. The BM member is the aquifer that lying under the BO member. It can be called the lower aquifer. The BO member is upper aquifer (figure 3.1). The average thickness of BM member is 27 meters and the BO member is 34 meters. The extension of these aquifers is distributed throughout the study area that the thickest bed usually appeared in the central part of area. The elevation of piezometric level is about 150 meters above mean sea level. This level is appeared above the ground surface in the northern part. This is the draining force of the artesian system in the study area.

3.2 The reserve of groundwater

The reserve of groundwater in this area is calculated by the amount of porosity multiply with the thickness of formation. It obtained from the dry unit weight (apparent specific gravity) and the average unit weight of the particles comprising each sample (absolute specific gravity) to determine the porosity by the following formula (Cohen, 1962):

$$n = 100x(\gamma_s - \gamma_d)/\gamma_d \qquad \text{———————————} \qquad 3.1$$

where n = porosity, in percent by volume

γ_s = average unit weight of the particles comprising the sample in grams per cubic centimeter (absolute specific gravity)

γ_d = dry unit weight of the dry disturbed or repacked sample, in grams per cubic centimeter (apparent specific gravity)

The absolute specific gravity of the samples was determined by the pycnometer method. The dry unit weight of the samples was determined by measuring the volume and weighing the oven-dried sample.

As the table 3.1, the porosity is calculated from the differential ratio of volume between the sediments in aquifers and the absolute volume. Then the reservoir of groundwater in each aquifers are calculated from the average thickness of member BM as 34 meters and the member BN as 27 meters in their areal extension about 140 km^2. The porosity is in the range of 36.51 to 45.45% in BM member and 37.27 to 48.82% in BO member. After calculated the amount of least groundwater reserve from the value that inserted in the equation 3.1 of this study area. The result of maximum reserve of BM member, the lower aquifer, is in the well No. MG 1459 at Ban Non Pheka about 171,190 m^3 and the minimum is in the well No. MG 1460 that situated between Ban Non Pheka and Ban Nong Waeng about 138,020 m^3. In BO member, upper aquifer, the maximum reserve is in the well No. MG 1459 about 232,390 m^3 and the minimum is shown in the well No. MG 1460 about 177,395 m^3. From these data, it can be implied the gross reserve of this study area is at least 315,000 m^3.

3.3 Pumping test

The pumping test data is operated after finished the groundwater wells. The data is consisted of static water level (SWL), piezometric level (PL), drawdown (DD), yield of water, time of operation, setting, and casing (appendixes D). The data is operated to get the flow rate (Q), the transmissivity (T), and the storativity (S).

The flow rate is the amount of groundwater that drained from the groundwater wells in the unit of m^3/hr. These values in each groundwater wells are not uniform. It is depending upon the hydraulic conductivity, transmissivity of the screen zone, and storativity of the sediments characteristic. The high value will give resulted to the large quantity of flow rate.

The hydraulic conductivity is a property of the aquifers that defined ability to transmit a fluids (table 3.2). It is independent of the fluid properties

No.	name	dept (m.)	g	cm^3	g/cm^3	g/cm^3	porosity %	member	Thickness (m.)	Q (m^3)
1	MG1459	84-85.5	21.70	16.00	2.65	1.36	48.82	BO	34	232,390.00
2	MG1459	127.5-129	23.13	16.00	2.65	1.45	45.45	BM	27	171,790.00
3	DP260	81-82.5	23.78	16.00	2.65	1.49	43.92	BO	34	209,035.00
4	DP260	111-112.5	26.49	16.00	2.65	1.66	37.52	BM	27	141,840.00
5	RTA15	61.5-63	17.73	12.50	2.65	1.42	46.48	BO	34	221,220.00
6	RTA15	120-121.5	19.47	12.50	2.65	1.56	41.22	BM	27	155,820.00
7	MG1460	64.5-66	20.78	12.50	2.65	1.66	37.27	BO	34	177,395.00
8	MG1460	105-106.5	21.03	12.50	2.65	1.68	36.51	BM	27	138,020.00

Table 3.1 The porosity value that calculated from the weight by volume.

Rocks	hydraulic conductivity meters/day
Clay, silt	0.000041-.082
Sand	4.1-123
Gravel	41-615
Sand and gravel	8.2-205
Sandstone	0.0041-2.05
Shale	0.00000041-0.0041

Table 3.2 The general hydraulic conductivity of several type of rocks.

The term transmissivity (T) is widely employed in groundwater hydraulics. It may be defined as the rate at which water of prevailing kinematics viscosity is transmitted through a unit width of aquifer under a unit hydraulic gradient. It follows that

$$T = Kb = (m/day) = m^2/day \qquad \text{———————} \quad \text{equation 3.2}$$

Where b is the saturated thickness of the aquifer.

Storativity is defined as the volume of water that an aquifer released from or takes into storage per unit surface area of aquifer per unit change in the component of head normal to that surface. In most confined aquifer, values fall in the range $0.00005 < S < 0.005$, indicating that large pressure changes over extensive areas are required to produce substantial water yield.

The hydrogeologic properties of aquifer that mentioned above are measured in the pumping well and in observation wells penetrating the aquifer. Graphs of drawdown versus time after pumping started is used to solve the equations which express the hydrogeologic properties of an aquifer and aquitard.

Drawdown is the data that record in the observation well after the pumping started. It is the differences between extrapolated stages of the water level that would have been observed if the well had not been pumped and water levels measured during the pumping period are computed.

The methods that used to solve the transmissivity and storativity are Theis's method and Jacob's method. The Theis's method is used the equation 3.5, 3.6, and the intersection point of logarithmic graph between time-drawdown type curve and the relation of r^2/t and drawdown of the pumping well. The match point or overlapping part of the curves determines mutual values of w(u), u, s, and r^2/t which may be inserted in equation 3.5 and 3.6 so that these equation may be solved for T and S.

$$s = 114.6Qw(u)/T \qquad \text{———————} \qquad \text{equation 3.5}$$

$$u = 1.87\,S\,r^2/Tt \qquad \text{———————} \qquad \text{equation 3.6}$$

where s = drawdown, in feet, measured in an observation well due to constant discharge of a pumped well

Q = discharge of a pumped well, in gallons per minute

T = transmissivity, in gallons per day and per foot

r distance, in feet from pumped well to observation well

S coefficient of storage, dimensionless

t time in days since pumping started

and the Jacob's method that used the equation 3.7 and 3.8 and the relation of drawdown and time since pump started in semilogarithmic graph

$$T = 0.183\ Q/\Delta s \qquad \text{———————— equation 3.7}$$

$$S = 2.25\ Tt_0/r^2 \qquad \text{———————— equation 3.8}$$

where T = coefficient of transmissivity, in m^2/day

Q = pumping rate, in m^3/day

Δs slope of the time drawdown graph expressed as the change in drawdown between any change in drawdown between any two times on the log scale whose ratio is 10 (one log cycle)

S storage coefficient

T_0 intercept of the straight line at zero drawdown, in days

R **distance, in m, from the pumped well to the observation well where the drawdown measurements were made**

The Jacob's method is differ from the Theis's method that the used of small values of u (that is, for small r and (or) large t) compared to $\log_e u$.

In this test, it is used the recovery test method (Driscoll, 1986) to solve the transmissivity (equation 3.7). The well No. MY 857 is used to be the represented well to show (figure 3.2). This method is used the pumping data and plotted the relation of drawdown and times after pumping started in semilogarithmic paper that inserted several resulted value in the equation 3.7. The yield of groundwater is 15.28 m^3/day and Δs is 6.3 then computed value of transmissivity is 10.56 m^2/day.

From the unpublished data (personal communication of the Groundwater Division, DMR.), the hydraulic conductivity is 0.2-8 m/day and the storativity is 7×10^{-5}.

Figure 3.2 The recovery curve of MY 857 B2 plotted between time and draw down.

3.4 Groundwater quality

The groundwater quality of both aquifers are analyzed by Groundwater Division, DMR. There are numerous data of dissolved constituents in groundwater. In this study, many of indicators are used to classify the groundwater as mention in chapter I. The classification of groundwater quality is based on the standard of drinking water of Groundwater Division, DMR., 2534. It is used to separate the zone of groundwater quality in both aquifers as follow:

3.4.1 BM Member

The lower aquifer, member BM has a few data of the groundwater quality. Most of the data is concentrated in the southwestern part. There are the value of pH, electrical conductivity, and several components as Fe, Cl, NO_3, F, TDS, and TH.

The hydrogen-ion concentration is expressed as the pH, which is the reciprocal of the logarithm of the hydrogen-ion concentration in moles per liter. A neutral water has a pH of 7.0 which indicates an equal number of $H^+$and OH^- ions; and alkaline water has a pH of more than 7.0 which indicates a preponderance of OH^- ions; and an acidic water has a pH of less than 7.0, which indicates a preponderance of H^+ ions. The pH of pure water at 25^{o}C is 7.0.

The distribution of pH value in this aquifer is illustrated in the figure 3.3. They have the variation from 6 to 8 that the pH lower than 6.5 are scattered and distributed in the southern part. Comparison with the natural water, which is in the range of 6 to 8.5 the results is still confined with normal limits.

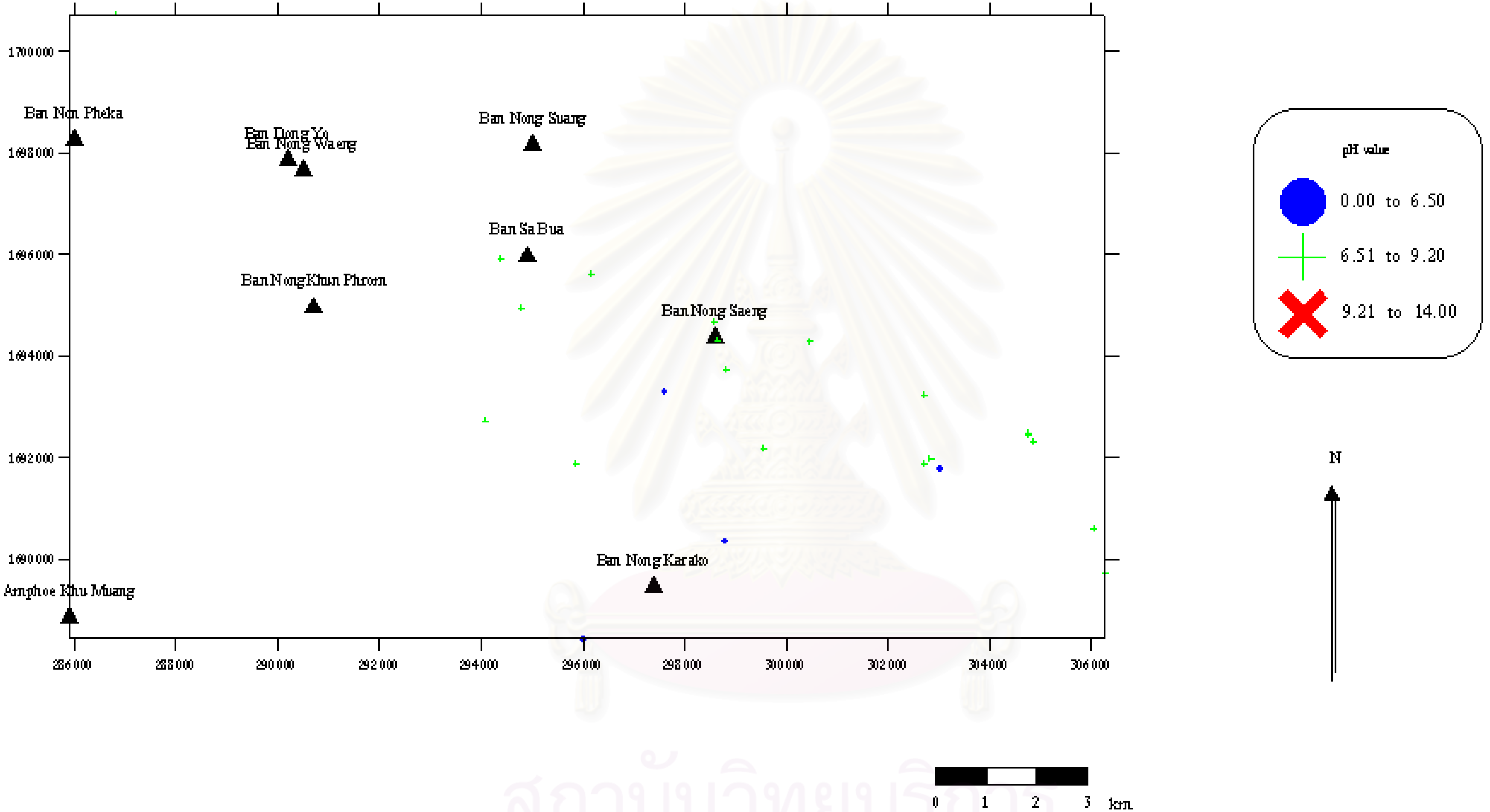

Figure 3.3 the distribution of pH value in the member BM.

The electrical conductivity is the ability of groundwater to conduct an electrical current. It is depended on the temperature, type of ions present, and concentration of various ions. Most of the electrical conductivity in the groundwater is common in the range of 30 to 2,000 micromhos, except the 3 wells No. MG 1474, DP 260, and JJ 11326 that situated closest to the northern part (figure 3.4). Its showed the distinct value over 5,000 micromhos and it seems that the line connected these 3 wells can be used as a boundary to separate the zone in to A and B zone that will discuss later with the total dissolved solid.

The other component is iron that formed in solution thought to be ionized. The sources of the important minerals for iron are pyroxenes, amphiboles, magnetite, pyrite, and biotite. Groundwater which having a pH between 6.0 and 8.0 may contain iron as much as 10 mg/l. The distribution of each value report is random. Most iron detected are in the range over 1 mg/l (figure 3.5). The highest iron detected is 8 mg/l. It is not suitable for drinking before the removal of iron. However, the reducing environment in the aquifer may indicated by the high iron content.

Manganese in solution is very similar to that of iron. In natural waters its concentration is less than one half of iron. A small number of acid water have been analyzed contained more than 1 ppm, but most water contain less than 0.2 ppm. In the area, most of manganese value is under 0.2 mg/l and the others are not more than 1 mg/l obtained from wells that are randomly scattered in the area (figure 3.6).

Next are the other components as nitrate and fluoride (figure 3.7 and 3.8). The nitrate component is found to contain less than 10 ppm which lied in the normal range of groundwater. The fluoride component is contain less than 1 mg/l.

Chloride is a major dissolved constituent of most natural water. Most of it come from 4 different sources as ancient seawater entrapped in sediments, solution of evaporite deposits, concentration by evaporation, and solution of dry fallout from the atmosphere. The chloride contents in the shallow groundwater in regions of heavy precipitation generally less than 30 ppm. Concentration of 1,000 ppm or more are

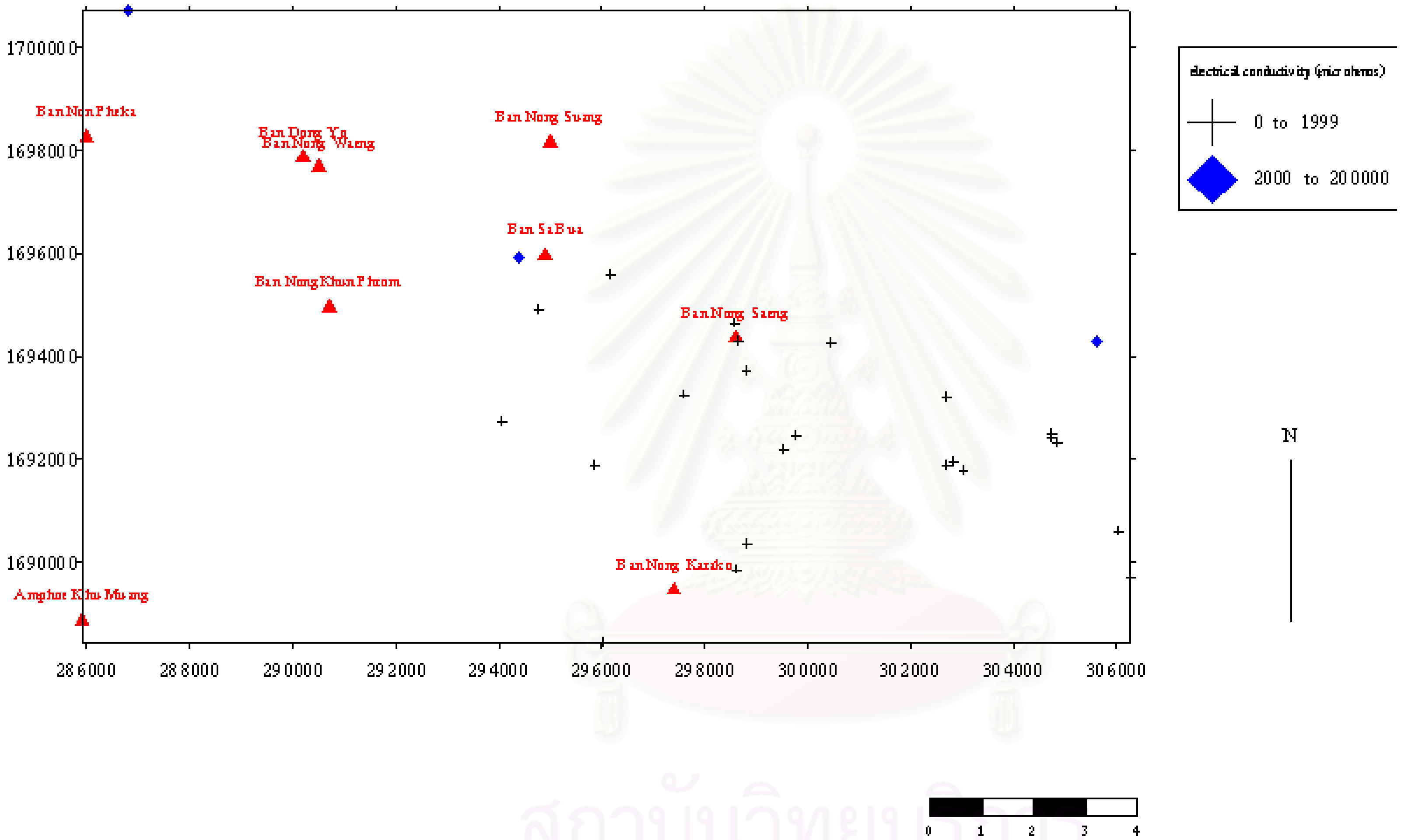

Figure 3.4 The electrical conductivity of member BM.

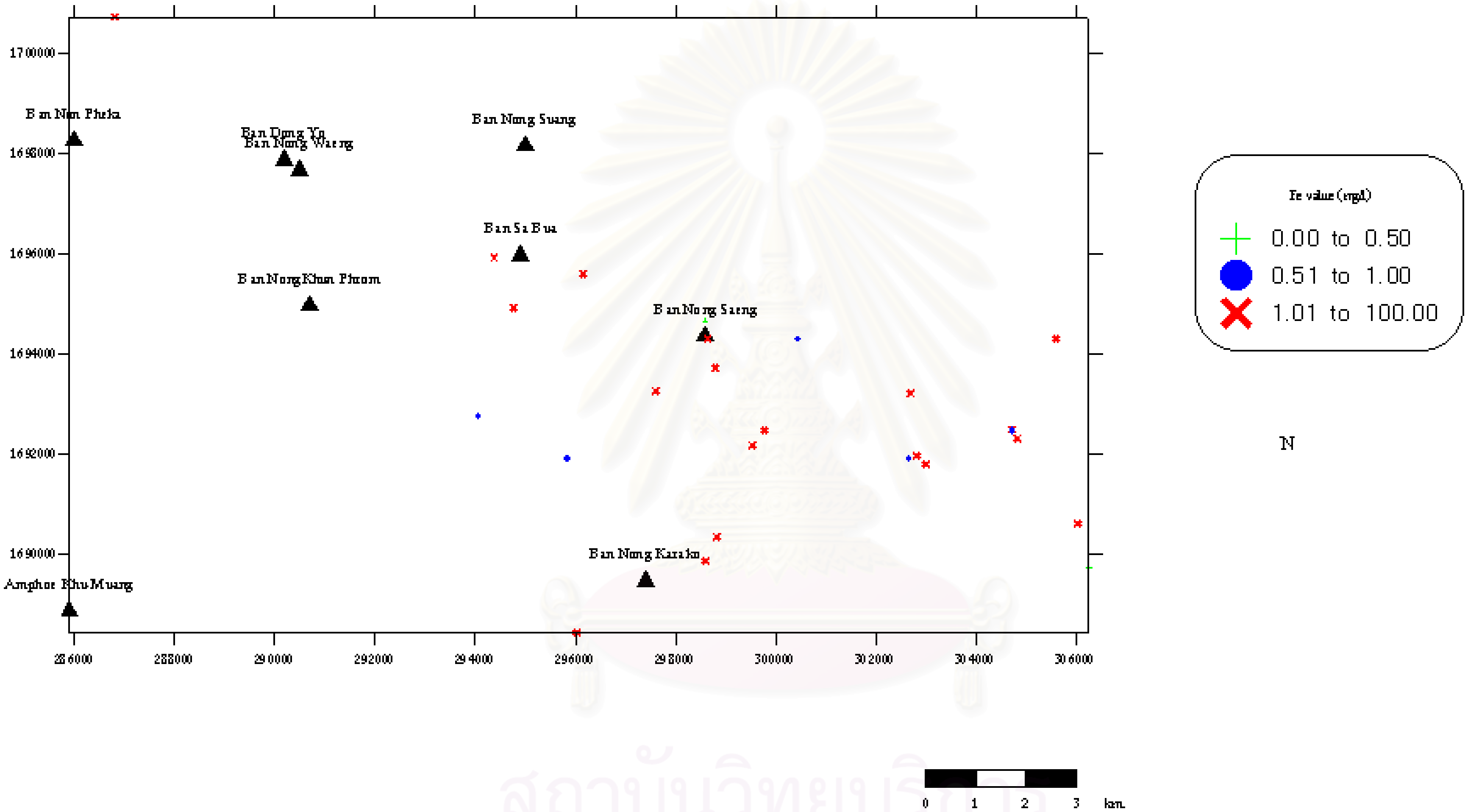

Figure 3.5 The distribution of Fe value in the member BM.

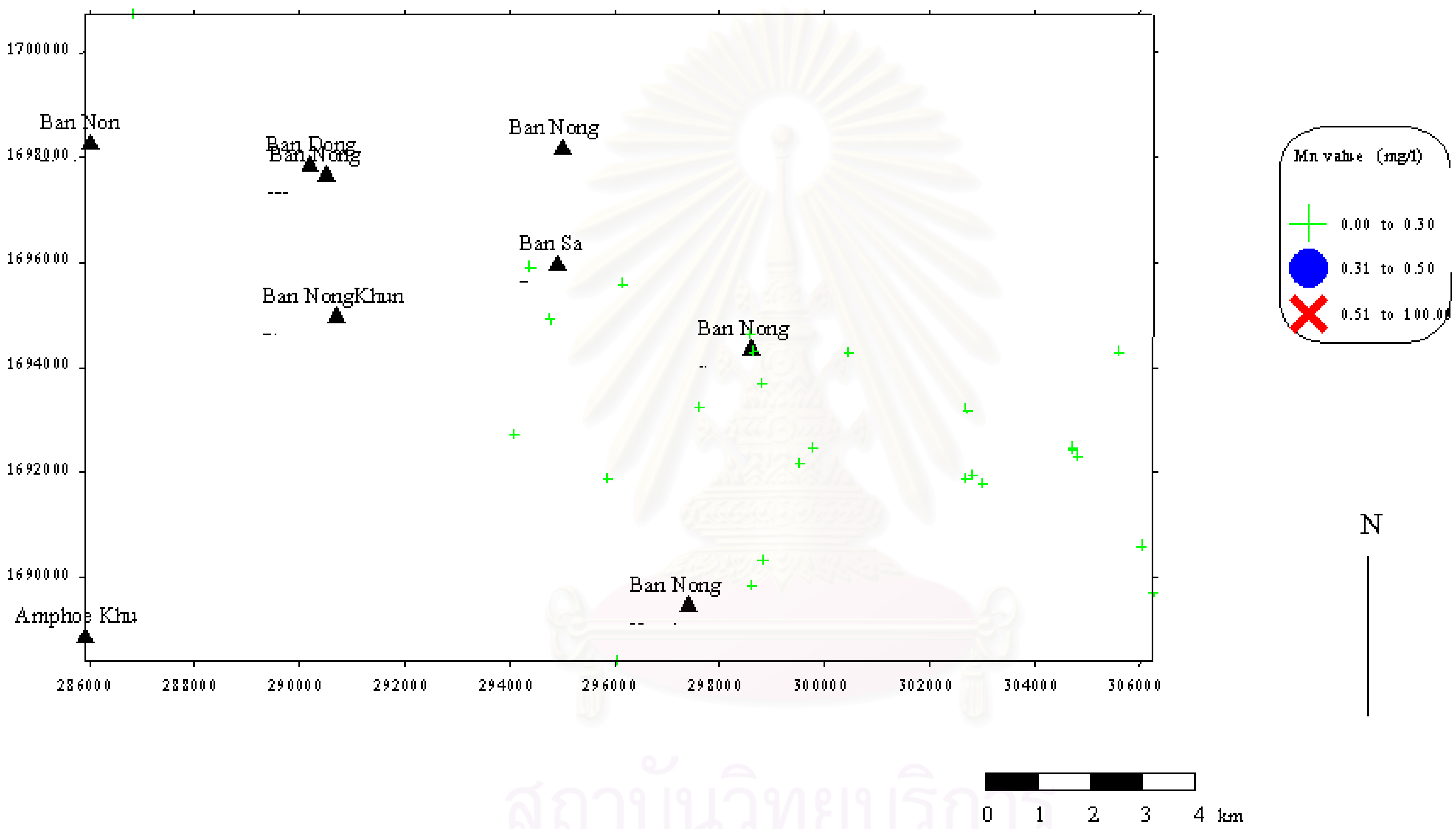

Figure 3.6 The distribution of manganese value of the member BM.

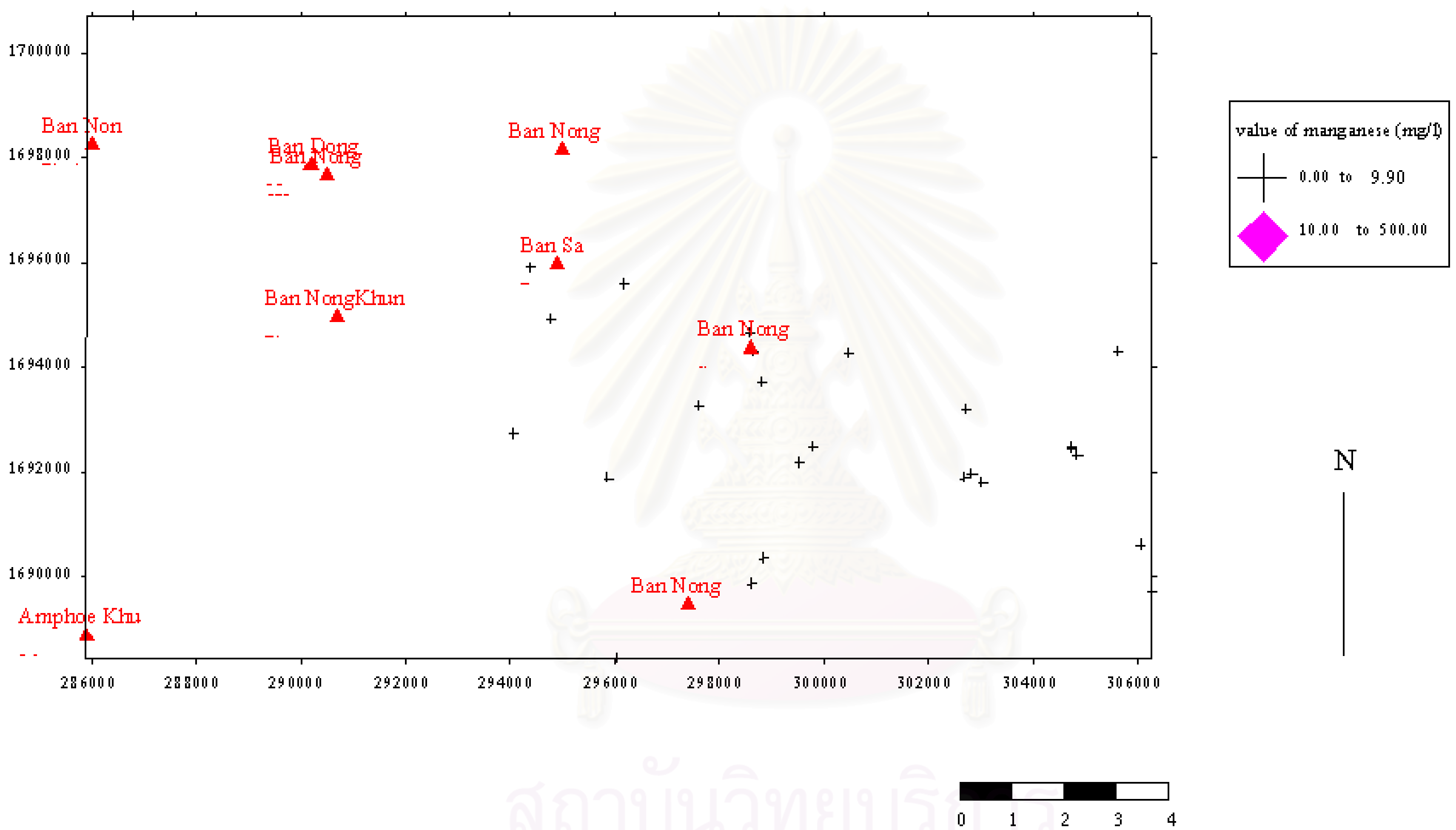

Figure 3.7 The distribution of nitrate value of BM member.

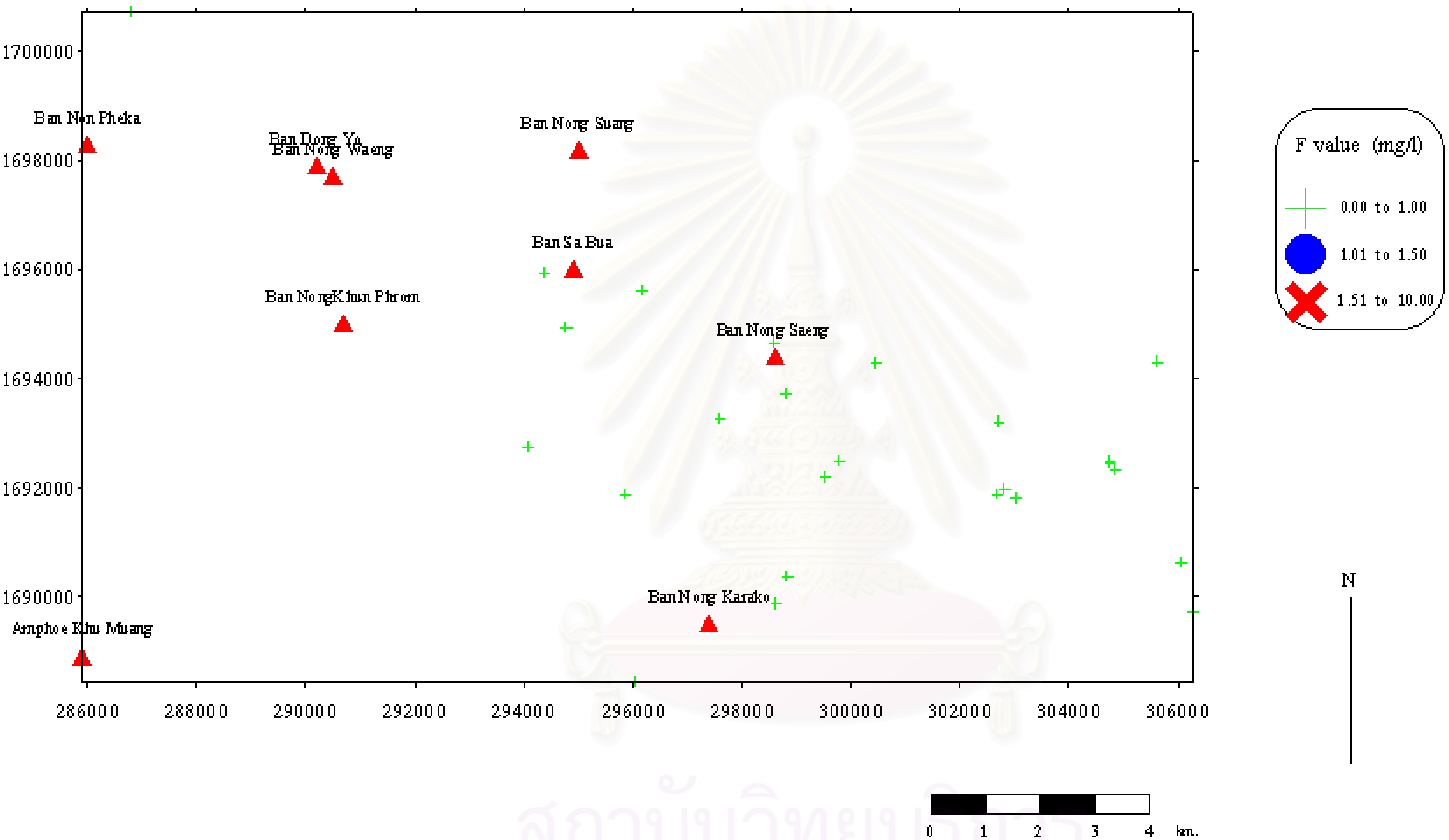

Figure 3.8 The distribution of fluoride value of member BM.

common in groundwater from arid regions. Most of the values derived from the study area are less than 1,000 ppm except in the 3 wells that have chloride content to be over 2,000 ppm (figure 3.9). The distribution of these 3 wells if connected, it can be used as a boundary line to separate the areal extension of fresh and brackish water zone.

The others important values are the total dissolved solid. It includes all solids material in solution. It does not include suspended sediment, colloids, or dissolved gases. Most values of the total dissolved solid in this area are less than 1,000 ppm except the 3 wells that mentioned above (figure 3.10). These 3 wells position situated in line at the upper north part of the study area and can be separated the area into 2 zone. Zone A is situated to the north is the zone of high total dissolved solid and refer to high electrical conductivity which also indicated high chloride content. Zone B is the zone of low total dissolved solid. These mean that zone A is the zone of saline water and zone B is the zone of fresh water.

The last data on quality of water is the total hardness. It is the results from the presence of divalent metallic cations, of which calcium, magnesium, carbonate, and bicarbonate are the most abundant in groundwater. The classification of hardness is soft with the value of 0-75 mg/l and moderately hard to hard with the value 75-150 and 150-300 mg/l. The distribution of the total hardness in cluster can be used to separate the area into 2 parts (figure 3.11). Compared with the standard of drinking water, the quality data of total hardness are in the zone of drinking.

3.4.2 BO Member

In the upper aquifer, the BO member which is the main aquifer provided that a lot of data available throughout the study area. The pH value is in the range of 6-8 which shows normal values nothing different from the natural water of BM member. Most values are in the range 6.5-9.2 which are still allowable on standard drinking water.(figure 3.12). But there are some of wells show the value under 6.5. They are distributed in the north of the area.

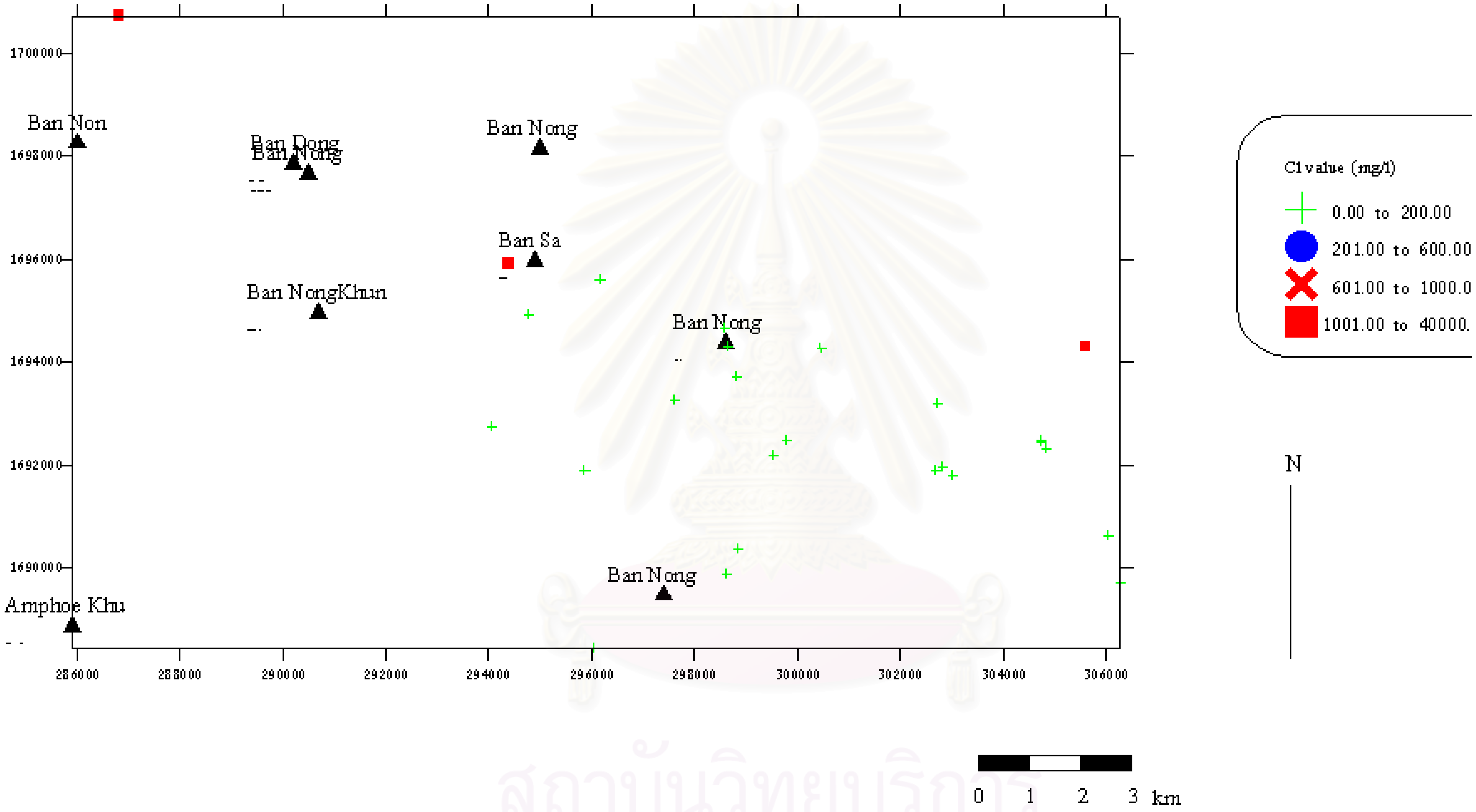

Figure 3.9 The distribution of Cl value in the member BM.

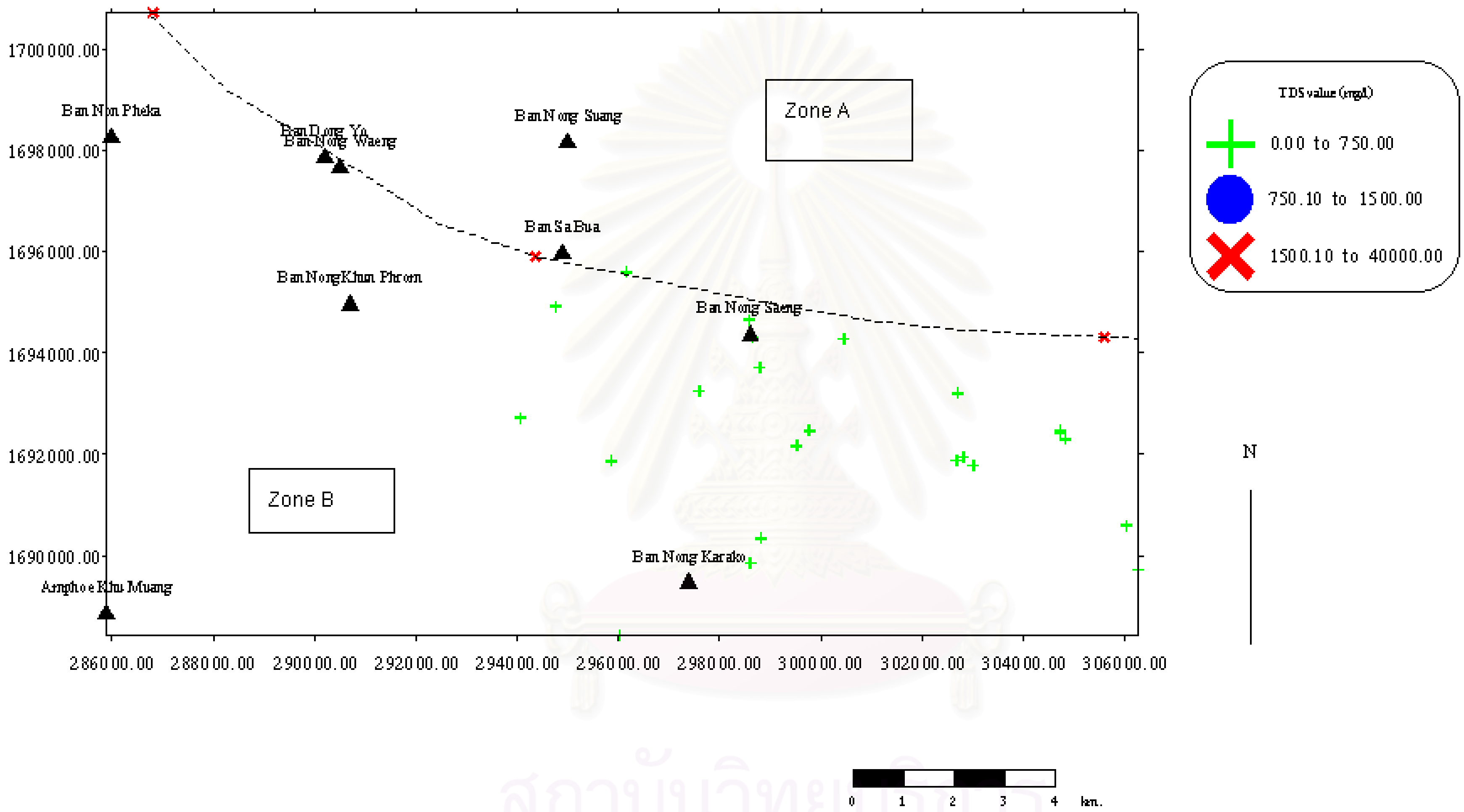

Figure 3.10The distribution of total dissolved solid value in member BM.

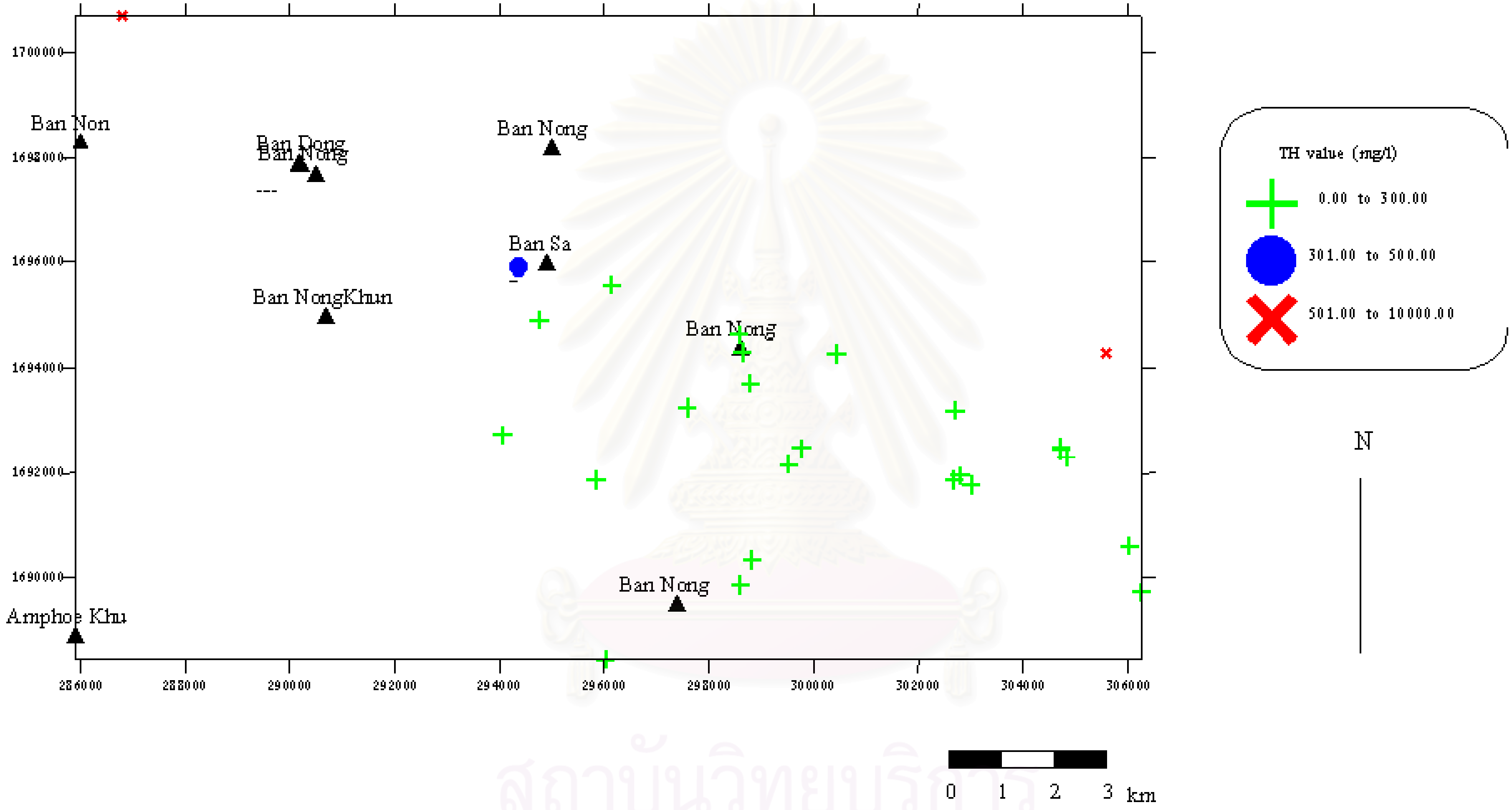

Figure 3.11 The distribution of total hardness value in member BM.

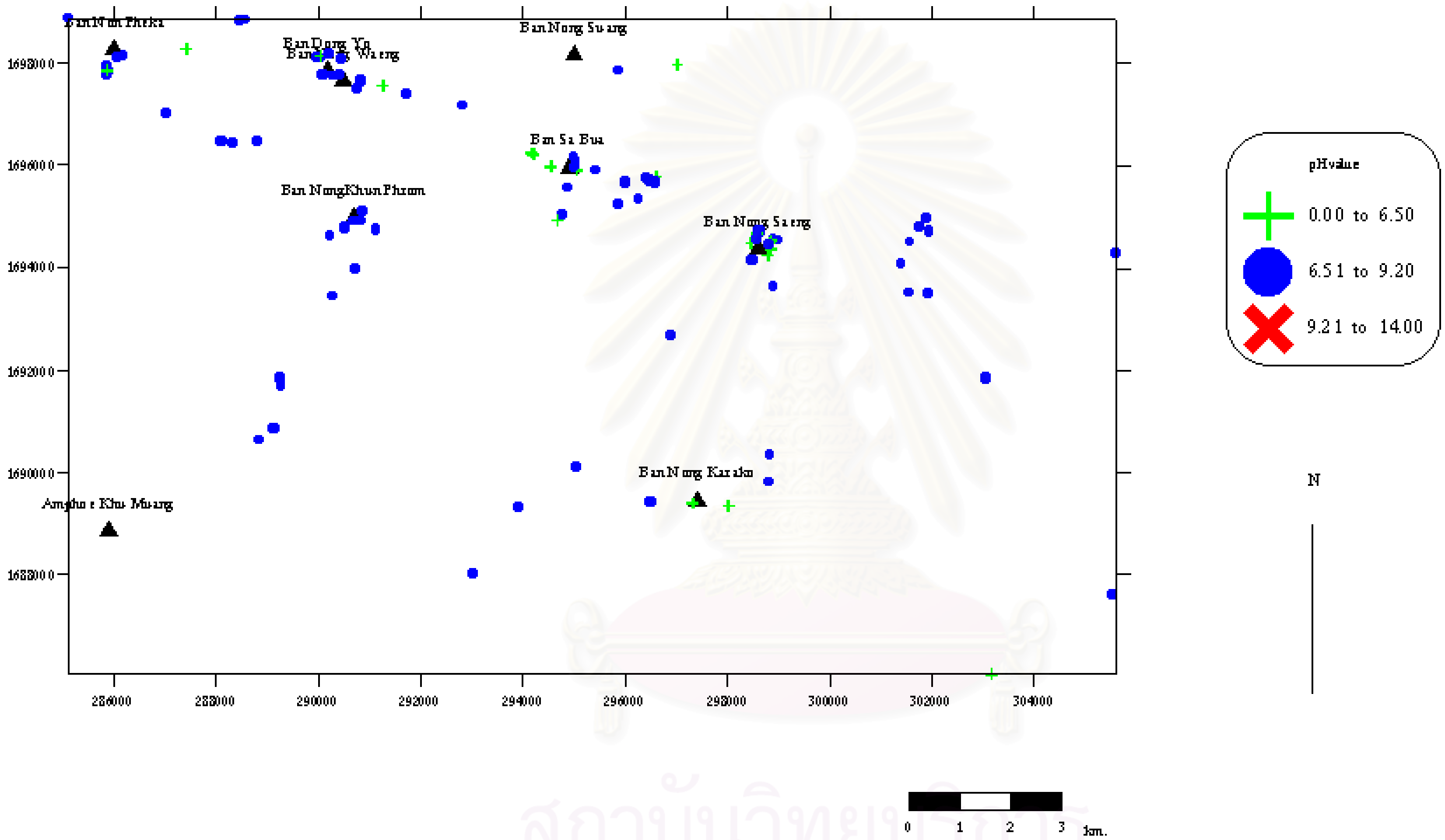

Figure 3.12 The distribution of pH value in the member BO.

The electrical conductivity value obtained from this member did not showed any distinctive character. They are not over 2,000 micromhos then it can not be separated into zone A and zone B as the lower aquifer (figure 3.13).

The iron content is varied from 0.02 to 11 mg/l and their distribution is randomly appeared in the area (figure 3.14). The wells produced higher values of iron content are situated in the northern part. The values are over standard of drinking water.

The manganese content can be separated in to 3 zones as the zones of manganese content less than 0.30 mg/l, the zone of 0.30-1.00 mg/l and the zone of more than 1.00 mg/l. The zone of more than 0.30 mg/l are appeared in the central and eastern part of study area (figure 3.15). The high value of manganese would be derived from the dissolved water in the zone of basaltic rock that situated in the southern part of Changwat Buri Ram.

The value of nitrate and fluoride found does not show any different from the normal groundwater content. They are less than 10 mg/l for nitrate and 1 mg/l for fluoride. (figure 3.16 and 3.17).

The chloride content in this aquifer is quite uniformly distributed. They are commonly less than 1,000 mg/l and can not be separated into zone like previous aquifer (figure 3.18).

The total dissolved solid values obtained are conformed with the other data as electrical conductivity values and chloride content which indicated only fresh water distribution available (figure 3.19).

The total hardness is higher value than the underneath aquifer. The soft groundwater is distributed in the central of study area and the moderately to hard groundwater is concentrated in the southern part of the area (figure 3.20).

The groundwater quality of both aquifers are not different in the south and central part but its different in the northern part. These are probably due to both

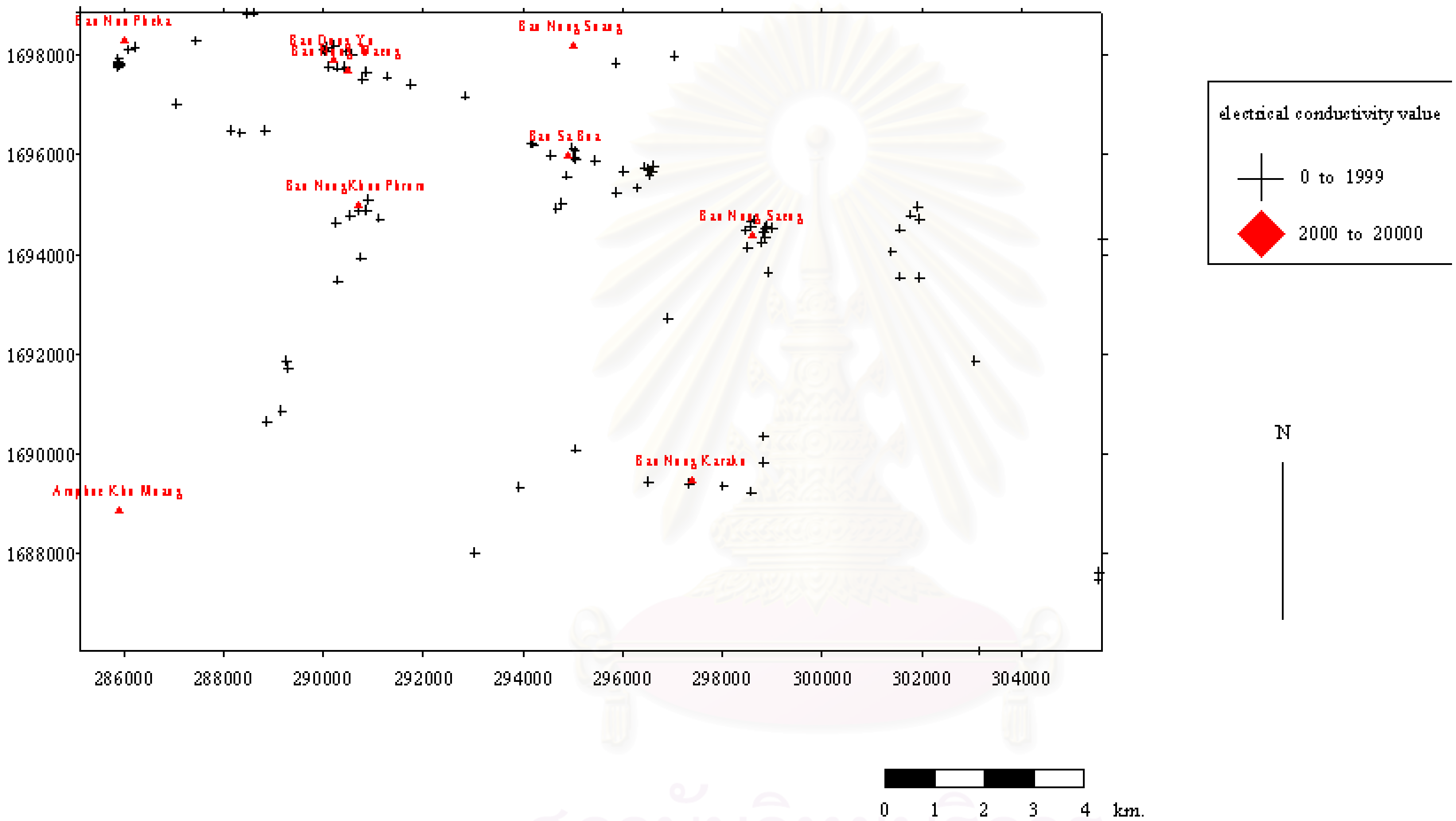

Figure 3.13 The distribution of electrical conductivity value in member BO.

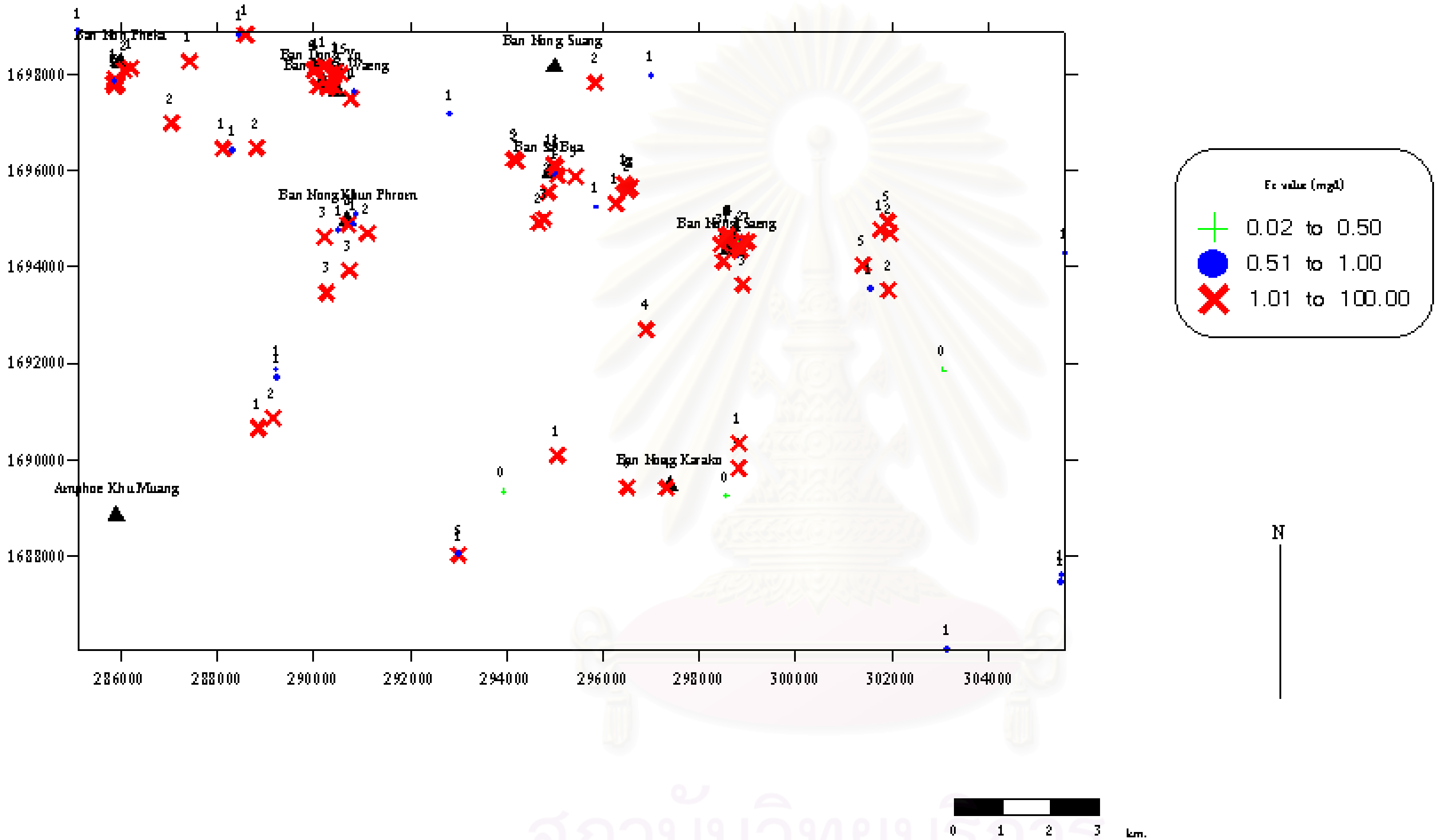

Figure 3.14 The distribution of Fe value in the member BO.

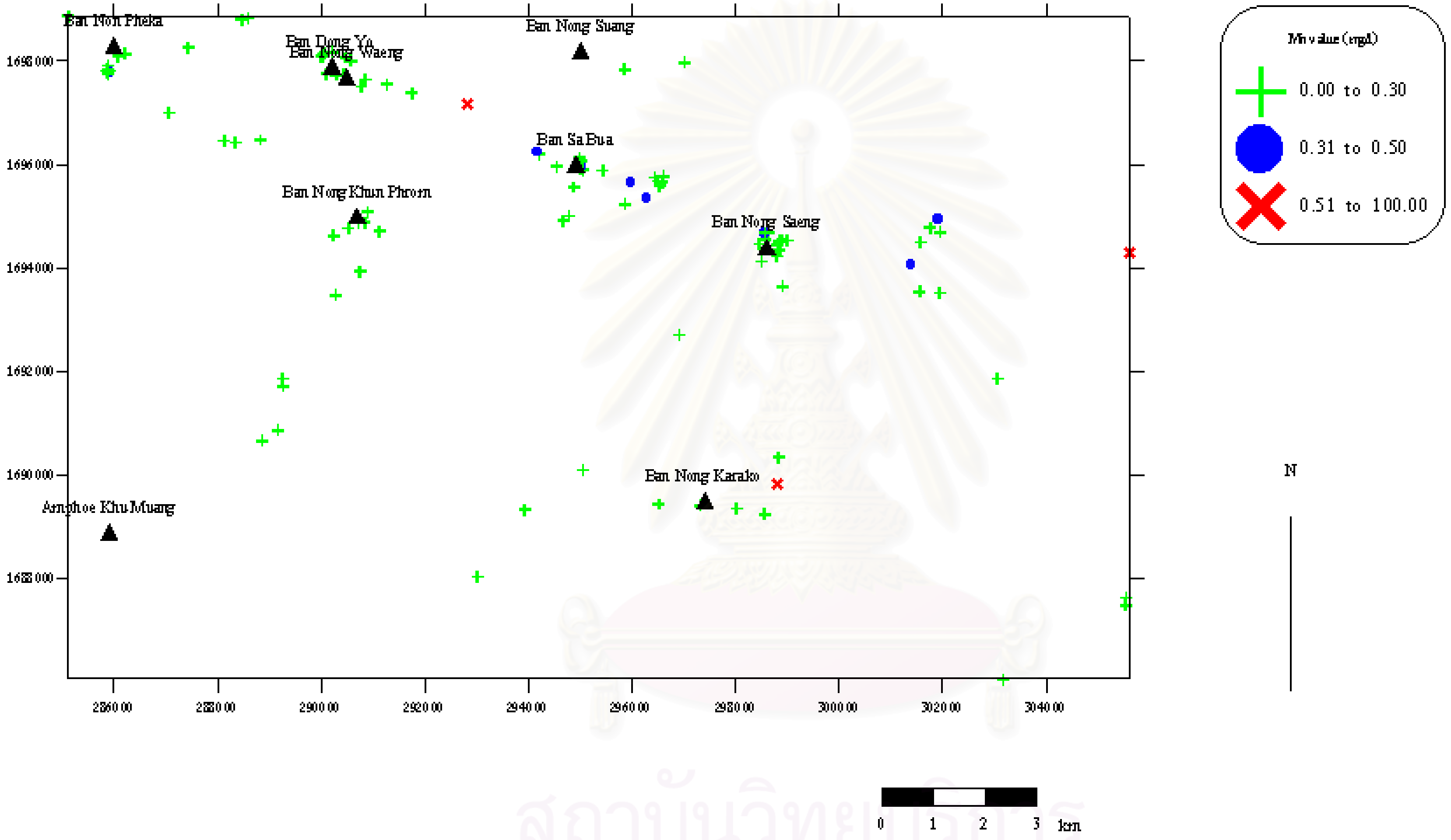

Figure 3.15 The distribution of manganese value in member BO.

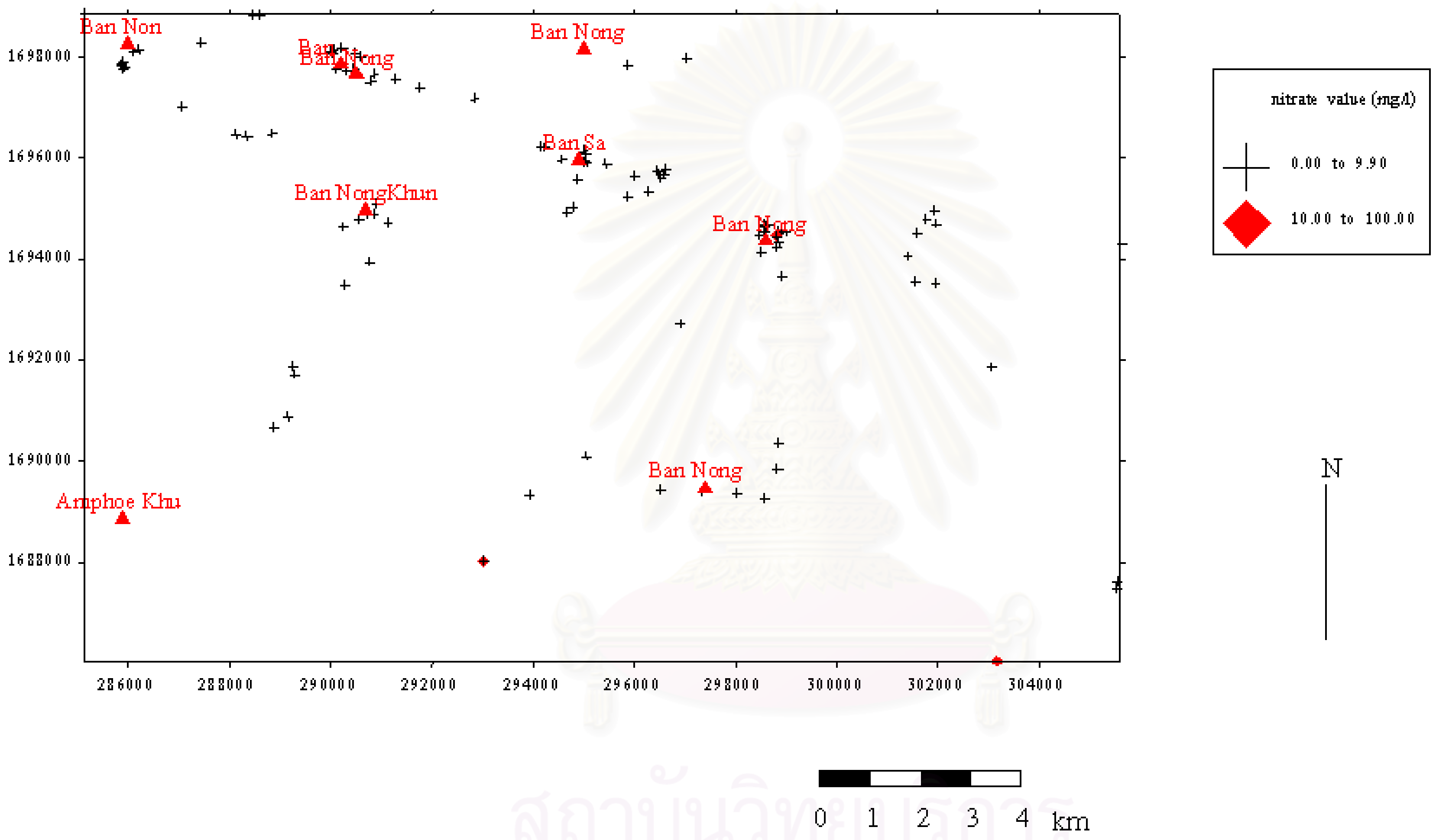

Figure 3.16 The distribution of nitrate value in member BO.

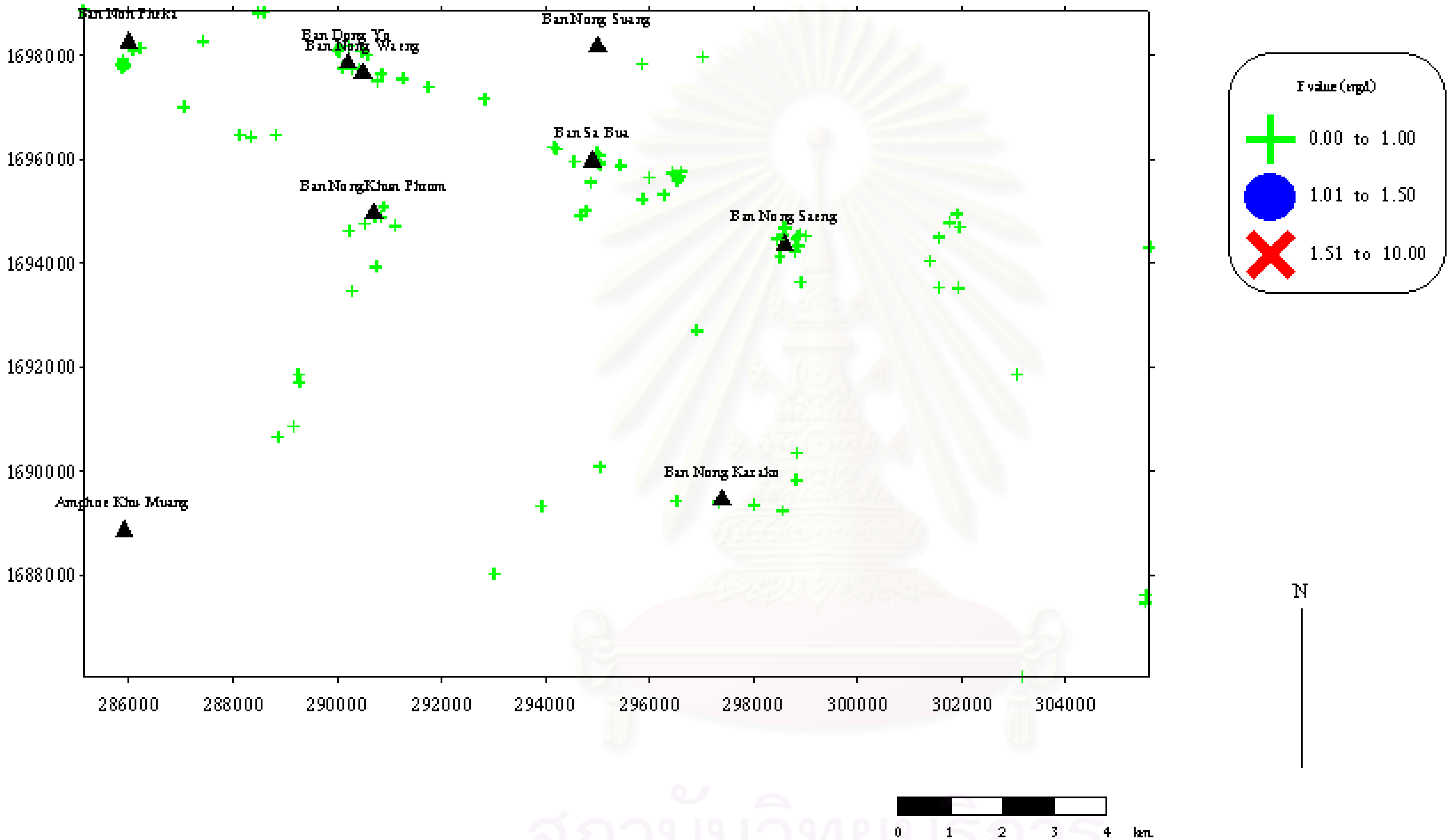

Figure 3.17 The distribution of fluorine value in the member BO.

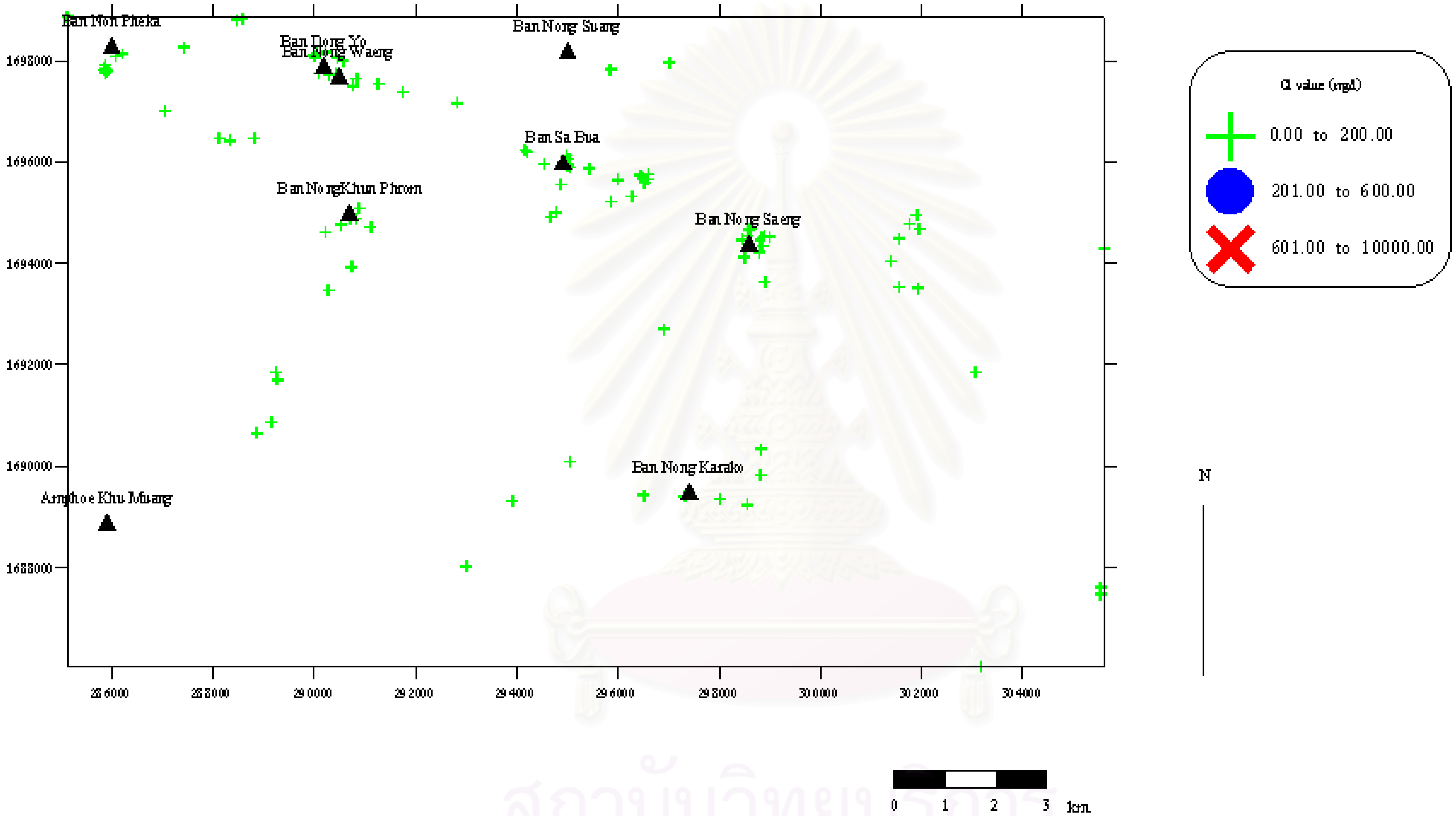

Figure 3.18 The distribution of Cl value in the member BO.

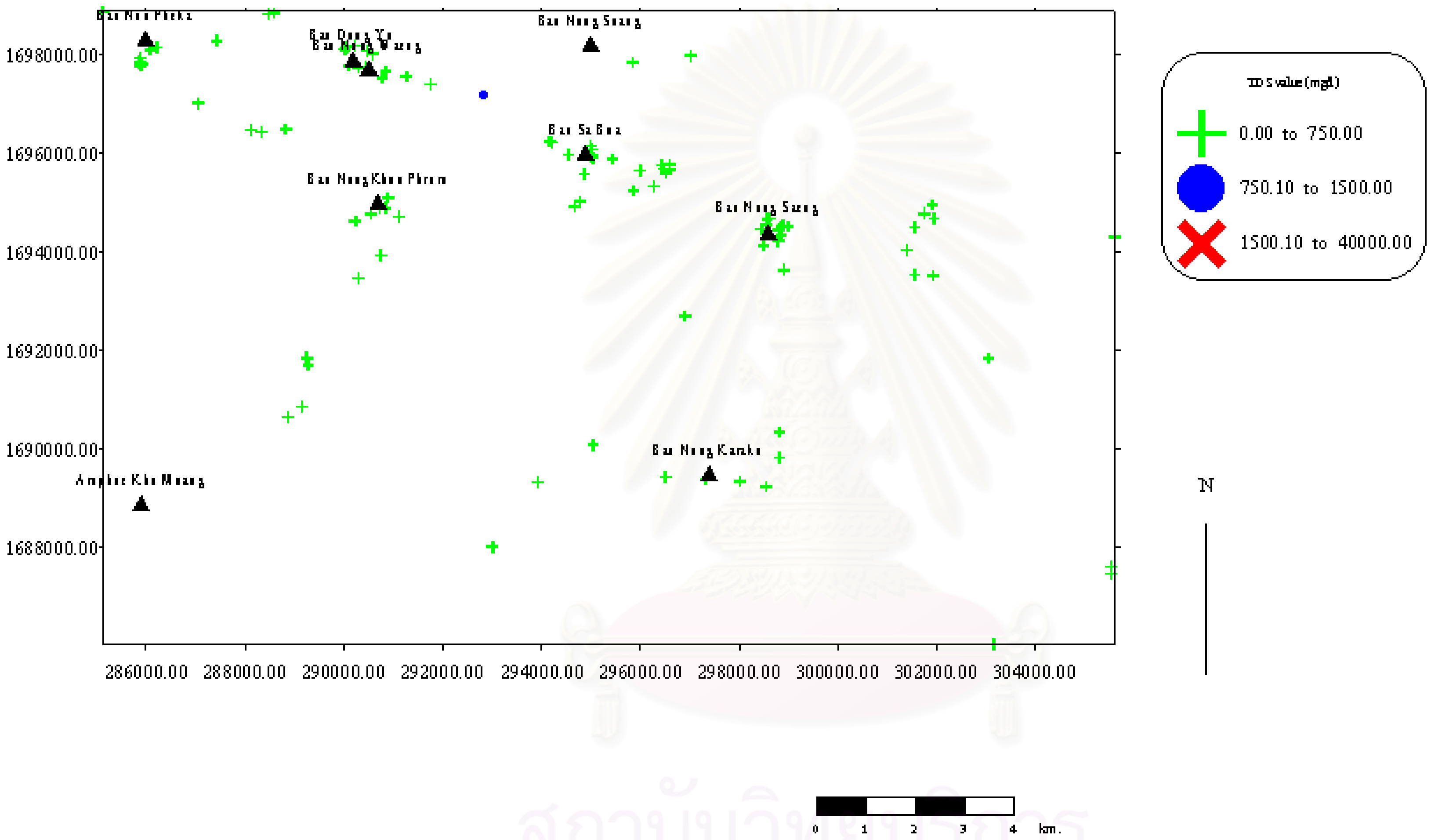

Figure 3.19 The distribution of total dissolved solid in member BO.

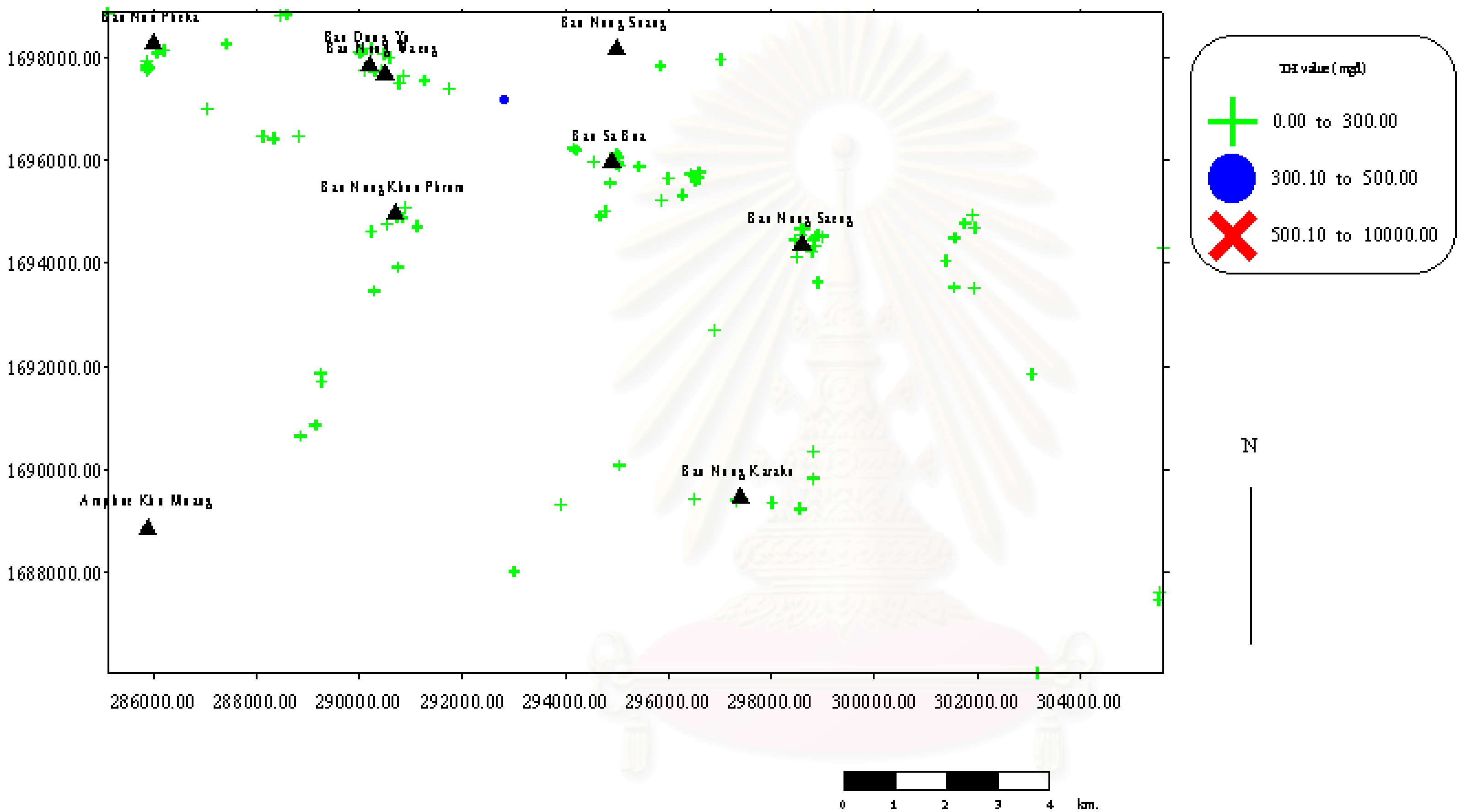

Figure 3.20 The distribution of total hardness value in the member BO.

aquifers have the same recharge area. While, the brackish water is invaded by saltier water in to the BM member from the north.

3.5 The groundwater model

The groundwater model of this study is defined to determine the extension of reservoir, the environment of deposition, and the extension of groundwater quality. The results are based on several data inputs as cuttings, E-logs, water quality data, and pumping test data to defined this model.

The recharge of this study area is situated in the high terrace appeared at southern part (figure 3.21). It located at the elevation about 200 meters above mean sea level and the elevation sloped down to the north in the area of confine aquifer underneath.

The extension of groundwater can be verified by the properties and abilities of reservoir. When its possessed good permeability and transmissivity with high porosity, its would be a good aquifer and, vice versa, its would be a poor aquifer or aquitard. In this study, it is found that hydrogeologic character of the formations can be divided into 2 type as aquifer and aquitard. There are 2 aquifers and 3 aquitards that previously mentioned in the early part of chapter III. The first aquitard appeared at the bottom and formed the basement formation A. It consisted mainly of red silty clay that is the reason why permeability and transmissivity are not so good. It can be referred to the environment of deposition of low energy with highly oxidizing environment. The salt dome tectonic in the past left some effects to this formation that appeared and illustrated as rolling topography. And this effect may be the sources of leakage and dissolution of salt to contaminate the aquifer.

The lower aquifer with almost uniform thickness extended in the north-south direction and become thicker to the east than the west direction. The characteristic of this aquifer is influenced by the salt dome tectonic. This aquifer showed finning upward sequence that referred to point bar deposit. The groundwater quality of this aquifer is separated into 2 zones by the TDS content. There are high contents of TDS value in the north that transgress as wedge shape thinning to the south. This characteristic is also controlled by the dispersion of saline water dissolved from the formation A with high density in comparison to fresh water of low density. This aquifer is trapped by 2 aquitards above as BN member and BP member to become confined aquifer.

The aquitard that lain over the lower aquifer is member BN. It consisted mainly of silty clay quartz that the permeability and transmissivity is very poor. The environment of deposition of this aquitard is reducing lacustrine deposit. It extends and become thicker to the north and west and thin out to the south and the east. The average thickness of this aquitard is 5 meters. This is one of the seal structures to separate the aquifer. Although this aquitard is separated the lower aquifer from the upper aquifer to protect the contamination between the aquifers. But their properties are not completely effective because of high porosity and saturation water may transmit an appreciable amount to or from adjacent aquifer. When fresh water was pumped out, the pressure within aquifer dropped will induced the saline water of still high pressure to invade the used to be fresh water region. Therefore, the saline water in the northern part of member BM has the possibility and potential to contaminate the upper aquifer.

The upper aquifer is BO member that confined between both aquitards of BN and BP members. The areal extension of this aquifer is not uniform in thickness. It laid down thickest in the central area and become thinning out in all directions as north, south, east, and west. Forming a body of lens shape. The environment of deposition referred to high energy fluvialtile deposit and it also showed finning upward sequence that indicated point bar deposit. The average thickness is 27 meters. The extension of groundwater quality in this aquifer do not varies to great extent. Many components of dissolved solid and structural control are indicated that the upper aquifer and lower aquifer have the same recharge from the south. These aquifer may join to become one. Since to the north, the aquifers become separated into an individual aquifer by BN and BP which are aquitards. There is fresh water throughout aquifer BO while aquifer BM there seem to possessed fresh water throughout only at the southern part. There seem to be some fresh water in the aquifer BM floats or ride on the brackish water at the bottom. The groundwater in BO aquifer has the possibility to be contaminated by the dispersion of the saline water from BM aquifer moved through aquitard, BN member.

The upper aquitard that formed as a seal bed of this area is BP member. It is the bed of yellowish brown silty clay composed mainly of quartz. The characteristic of this aquitard is saturated and low permeability. The extension of this aquitard is similar with the BN member that thicker to the north and thin out to the south. This member is played an important role that extends to high elevation to control the piezometric level as the figure 3.10. This is the mechanism of the artesian flowing well that found in the low elevation of southern part. The environment of deposition of this aquitard is formed in low energy lacustrine deposit in oxidizing condition. The average thickness of this aquitard is 5 meters.

The uppermost that lain over the upper aquitard is member BQ. This member is consisted of yellowish brown sand intercalated with silt and sand. The extension of this member is covered almost the entire study area. It is found the finning upward sequence which is the indication of the point bar deposits. Therefore, the environment of deposition is the recent fluvial deposit.

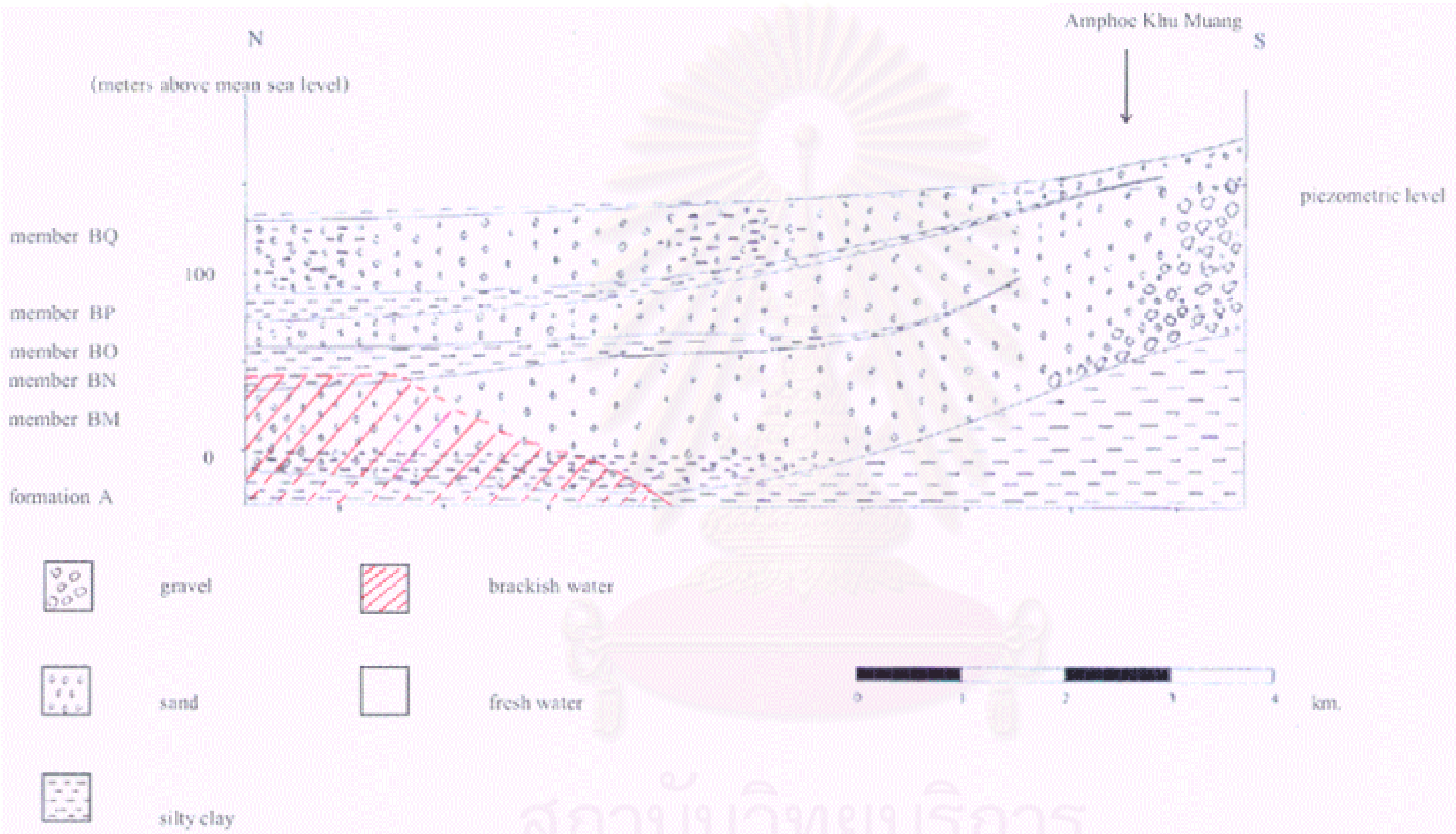

Figure 3.21 **Idealized groundwater modeling of Amphoe Khu Muang, Changwat Buri Ram and adjacent (cross section line D-D').**

3.6 Conclusion

The hydrogeology in the area can be classified the aquifer into 2 confined aquifers as the lower aquifer that is BM member and the upper aquifer that is BO member. These 2 aquifers are trapped by the upper aquitard, BP member. The characteristic and structure of the model indicated both aquifers are recharged from the same location at the southern part of the area. The character of groundwater wells are showed the artesian flowing well in the northern part of the area since the piezometic level in the southern part of area is higher than the surface of northern part of area. The groundwater reserve from both aquifers in the study area are at least is 315,000 m^3. The groundwater quality of the lower aquifer needs some treatment to improve the quality of iron since its content in excess 0.3 mg/l. The other is the A zone in the north of study area that has the high value of TDS which is not suitable for usage. The groundwater quality of this upper aquifer is good quality water but it should be treated to improve the excess of iron and managanese content which the value are over 0.3 mg/l.

The model of groundwater is the alternation of sediments that can be separated into aquifers and aquitards. The subsurface structure of the sedimentary deposits is decline from south to north that led to the elevations of each formation are also decrease from south to north. By the way, The 2 aquifers are confined by the upper aquitard that the artesian water wells phenomenon are appeared in the northern part of area. Because the piezometic level of the groundwater in the south is lower than the ground surface in the south so there is no any flowing well. The quality of groundwater in the lower aquifer can be divided into 2 zone. Zone A is bounded in the northern part that is the zone of brackish water. This zone is invaded by the water which dissolved salt from formation A, this brackish water is a potential invader to fresh water region on the south. Zone B is the zone of fresh water that has the good quality of groundwater. The upper aquifer has the good quality of groundwater except high value of iron content but it can be improved easily before usage.

Chapter IV

Conclusion and recommendation

4.1 Quaternary geology

1. The Quaternary stratigraphy of this area can be divided into 2 formations. The lower formation is A formation that laid throughout the area. The typical character is red color. The upper formation is B formation, consisted of 5 members divided by using the characteristic of sediment. The sequence are lying from bottom to top are as BM, BN, BO, BP and BQ. The BM and BO member are the thick beds of sand to gravel of pebble size sediment and showed the finning upward sequence. They are appeared to extend throughout the area. The other, BN and BP member are thin beds silty clay size, Their beds are extended from north to central part.

2. The A formation consists of some salt that is the source of brackish water in the northern part of area.

4.2 Hydrogeology

1. The hydrogeology in the area can be classified aquifer into 2 confined aquifers as lower aquifer that is the BM member and upper aquifer that is the BO member. These 2 aquifers artrapped by the upper aquitard, BP member.

2. The character and structure of the groundwater model indicated that both aquifers are recharged from the same location at the southern part of the area.

3 The groundwater wells in the north showed the phenomenon of artesian flowing well came from the piezometic level in the southern part is higher than the surface of northern part.

4. The reserve of groundwater from the both aquifers in the study area are at least is 315,000 m^3.

5. The model of groundwater is the alternation of sediments that can be classified as aquifers and aquitards. The subsurface structure of the sedimentary deposits is decline from south to north and the elevations of each formation are decreased from south to north, too. By the way, The 2 aquifers are confined by the upper aquitard that the artesian water wells are phenomenon in the northern part of area. Because the piezometic level of the groundwater in the south is higher than the ground surface in the north. The groundwater quality of the lower aquifer should be treated to improve the quality of iron that in excess of 0.3 mg/l.

6. The quality of groundwater in the lower aquifer can be divided into 2 zones based on their areal extent. Since there are 3 wells of high electrical conductivity values situated at the upper northern part of the study area. The connected line among these wells will separated the area into 2 zones. Zone A is situated to the north is a zone of high content of total dissolved solids indicated by high electrical conductivity which also referred to high chloride content. Zone B down south is a zone of low total dissolved solids content. These mean that zone A is the zone of saline water underneath and zone B is the zone of fresh water. The upper aquifer produced good quality of groundwater except some with high value of iron content which can be improved easily before usage.

4.3 Recommendation

The model of groundwater is pointed to the brackish water that situated in the north and transgress to the south in the confine aquifer. The discharge or production of groundwater will reduce the pressure in both aquifers will cause the dispersion of brackish water to contaminate the freshwater. It should prepare the plan to develop these aquifers by

1. Develop the recharge area for highest potential to recharge water by investigated the area of recharge to improve the potential of recharge.

2. To investigate and plan for the safe yield and highest amount of discharge of the confined aquifer to be balanced with recharge. This equilibrium will extend and prolong the life of groundwater well and also control the invasion of brackish water.
3. To produce natural flow of brackish water from the lower aquifer in rainy season in order to reduce the pressure of brackish water from lower aquifer in the north. These also help the freshwater recharge to gain a strong hold within the freshwater aquifer realm.

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Appendixes

List of appendices

Appendix I Wells reference number and depth information

No.	well number	UTMN	UTME	bp	bo	bn	bm	a	elevation (m.)	mean sea level elevation					thickness (m.)				
									msl.	BP	BO	BN	BM	A	BQ	BP	BO	BN	BM
1	AA1727B734	1694211	298174	13	48	102	126	204	139	126	91	37	13	-65	13	35	54	24	78
2	B2067B10	1689830	298814	7	18	25	58	94	160	153	142	135	102	66	7	11	7	33	36
3	CC1670B1	1698870	285119	48	52	57	73	NO	140	92	88	83	67	#######	48	4	5	16	#######
4	CC1671B2	1698738	285109	33	42	84	88	NO	140	107	98	56	52	#######	33	9	42	4	#######
5	CC1672B3	1698644	288661	19	31	67	87	NO	140	121	109	73	53	#######	19	12	36	20	#######
6	CC1673B4	1698830	288589	36	42	59	NO	NO	138	102	96	79	#######	#######	36	6	17	#######	#######
7	CC1674B5	1698811	288470	45	60	87	NO	NO	138	93	78	51	#######	#######	45	15	27	#######	#######
8	CC1675B6	1698212	288498	30	39	69	NO	NO	140	110	101	71	#######	#######	30	9	30	#######	#######
9	CC1676B7	1697001	287053	30	42	82	NO	NO	146	116	104	64	#######	#######	30	12	40	#######	#######
10	CC1677B8	1696420	288335	43	51	79	NO	NO	146	103	95	67	#######	#######	43	8	28	#######	#######
11	CC1678B9	1696474	288822	51	64	NO	NO	NO	146	95	82	#######	#######	#######	51	13	#######	#######	#######
12	CC1679B10	1696464	288125	39	NO	NO	NO	NO	146	107	#######	#######	#######	#######	39	#######	#######	#######	#######
13	CC1681B11	1695080	294557	21	39	87	NO	NO	142	121	103	55	#######	#######	21	18	48	#######	#######
14	DP260B1	1695921	295023	45	57	84	90	152	138	93	81	54	48	-14	45	12	27	6	62
15	DP264B5	1689432	296510	27	37	42	51	94	160	133	123	118	109	66	27	10	5	9	43
16	DP267B8	1697933	295110	30	52	72	102	117	132	102	80	60	30	15	30	22	20	30	15
17	DP270B11	1689240	298556	6	16	36	40	60	161	155	145	125	121	101	6	10	20	4	20
19	DP274B15	1687616	305528	12	24	27	54	60	135	123	111	108	81	75	12	12	3	27	6
20	DQ290B9	1695300	304500	10	12	36	75	93	130	120	118	94	55	37	10	2	24	39	18
21	L1734B2	1691873	295852	30	39	***	111	135	155	125	116	#######	44	20	30	9	#######	#######	24
22	L1746B14	1686156	302657	*	25	*	45	51	145	#######	120	#######	100	94	#######	#######	#######	#######	6
23	MG1459B32	1697799	285745	39	40	88	93	147	142	103	102	54	49	-5	39	1	48	5	54
24	MG1460B33	1696310	288276	26	30	93	102	132	146	120	116	53	44	14	26	4	63	9	30
25	MG1461B34	1690656	288862	34	51	60	70	79	173	139	122	113	103	94	34	17	9	10	9
26	MG1462B35	1691905	287333	27	39	NO	NO	61	160	133	121	#######	#######	99	27	12	#######	#######	#######
27	MG1463B36	1697783	287758	36	46	84	NO	NO	143	107	97	59	#######	#######	36	10	38	#######	#######
28	MG1464B37	1697699	285874	27	43	85	NO	NO	142	115	99	57	#######	#######	27	16	42	#######	#######

(continue)

No.	well number	UTMN	UTME	bp	bo	bn	bm	a	elevation (m.)	mean sea level elevation					thickness (m.)				
									msl.	BP	BO	BN	BM	A	BQ	BP	BO	BN	BM
29	MG1465B38	1697717	285882	NO	46	64	NO	NO	142	#######	96	78	#######	#######	#######	#######	18	#######	#######
30	MG1466B39	1697737	285889	18	34	79	NO	NO	142	124	108	63	#######	#######	18	16	45	#######	#######
31	MG1467B40	1697773	285872	36	40	84	NO	NO	142	106	102	58	#######	#######	36	4	44	#######	#######
32	MG1468B41	1697773	285853	24	27	78	NO	NO	142	118	115	64	#######	#######	24	3	51	#######	#######
33	MG1469B42	1697504	290771	39	77	82	NO	NO	138	99	61	56	#######	#######	39	38	5	#######	#######
34	MG1470B44	1697588	290627	46	82	87	NO	NO	138	92	56	51	#######	#######	46	36	5	#######	#######
35	MG1472B45	1697746	290431	48	78	NO	NO	NO	138	90	60	#######	#######	#######	48	30	#######	#######	#######
36	MG1473B46	1697582	290764	27	42	60	NO	NO	138	111	96	78	#######	#######	27	15	18	#######	#######
37	MG1474B47	1700721	286803	NO	NO	NO	NO	110	136	#######	#######	#######	#######	26	#######	#######	#######	#######	#######
38	MK1506B1	1694881	290717	21	24	84	109	144	148	127	124	64	39	4	21	3	60	25	35
39	MK1507B2	1694765	290532	30	46	NO	NO	NO	148	118	102	#######	#######	#######	30	16	#######	#######	#######
40	MK1509B4	1693417	290350	49	51	NO	NO	NO	155	106	104	#######	#######	#######	49	2	#######	#######	#######
41	MK1510B5	1695081	290886	39	42	NO	NO	NO	147	108	105	#######	#######	#######	39	3	#######	#######	#######
42	MK1511B6	1694882	290840	45	51	NO	NO	NO	147	102	96	#######	#######	#######	45	6	#######	#######	#######
43	MK1512B7	1694713	291114	34	37	NO	NO	NO	148	114	111	#######	#######	#######	34	3	#######	#######	#######
44	MK1513B8	1694621	290232	NO	48	NO	NO	NO	149	#######	101	#######	#######	#######	#######	#######	#######	#######	#######
45	MK1515B10	1697644	290846	NO	54	NO	NO	NO	139	#######	85	#######	#######	#######	#######	#######	#######	#######	#######
46	ML1492B10	1693200	302700	46	49	76	79	152	133	87	84	57	54	-19	46	3	27	3	73
47	ML1494B12	1694495	298946	43	49	69	79	169	138	95	89	69	59	-31	43	6	20	10	90
48	MY856B33	1697808	285920	NO	45	NO	NO	NO	142	#######	97	#######	#######	#######	#######	#######	#######	#######	#######
49	MY857B34	1697788	285913	57	60	77	NO	NO	143	86	83	66	#######	#######	57	3	17	#######	#######
50	MY858B35	1697916	285881	40	NO	NO	NO	NO	142	102	#######	#######	#######	#######	40	#######	#######	#######	#######
51	MY859B36	1697829	285873	21	25	82	NO	NO	143	122	118	61	#######	#######	21	4	57	#######	#######
52	MY860B37	1697756	285877	15	21	72	75	NO	144	129	123	72	69	#######	15	6	51	3	#######
53	MY861B38	1697820	285859	39	41	NO	NO	NO	143	104	102	#######	#######	#######	39	2	#######	#######	#######
54	MY862B39	1697801	285829	NO	42	NO	NO	NO	143	#######	101	#######	#######	#######	#######	#######	#######	#######	#######

(continue)

No.	well number	UTMN	UTME	bp	bo	bn	bm	a	elevation (m.) msl.	mean sea level elevation BP	BO	BN	BM	A	thickness (m.) BQ	BP	BO	BN	BM
55	MY864B41	1698137	286208	33	41	84	NO	NO	141	108	100	57	#######	#######	33	8	43	#######	#######
56	MY865B42	1698090	286079	NO	36	84	NO	NO	141	#######	105	57	#######	#######	#######	#######	48	#######	#######
57	MY867B44	1697849	285867	NO	40	83	NO	NO	142	#######	102	59	#######	#######	#######	#######	43	#######	#######
58	MZ1016B2	1698097	290001	NO	40	NO	NO	NO	138	#######	98	#######	#######	#######	#######	#######	#######	#######	#######
59	MZ1017B3	1698099	290020	45	52	75	NO	NO	138	93	86	63	#######	#######	45	7	23	#######	#######
60	MZ1018B4	1691490	288848	NO	36	75	NO	NO	168	#######	132	93	#######	#######	#######	#######	39	#######	#######
61	MZ1019B5	1691854	289250	30	35	NO	NO	NO	168	138	133	#######	#######	#######	30	5	#######	#######	#######
62	MZ1020B6	1691705	289271	27	33	NO	NO	NO	168	141	135	#######	#######	#######	27	6	#######	#######	#######
63	MZ1021B7	1690862	289157	NO	40	78	81	82	170	#######	130	92	89	88	#######	#######	38	3	1
64	MZ1022B8	1697551	291259	21	28	79	NO	NO	138	117	110	59	#######	#######	21	7	51	#######	#######
65	MZ1024B10	1698496	288951	28	31	70	NO	NO	138	110	107	68	#######	#######	28	3	39	#######	#######
66	MZ1025B11	1691226	290268	33	42	87	NO	NO	164	131	122	77	#######	#######	33	9	45	#######	#######
67	MZ1026B12	1698268	287425	34	46	72	NO	NO	143	109	97	71	#######	#######	34	12	26	#######	#######
68	MZ1027B13	1698681	289431	25	34	52	76	NO	139	114	105	87	63	#######	25	9	18	24	#######
69	MZ1028B14	1696600	288800	24	36	78	85	95	146	122	110	68	61	51	24	12	42	7	10
70	MZ1029B15	1696600	288800	NO	48	NO	NO	NO	146	#######	98	#######	#######	#######	#######	#######	#######	#######	#######
71	RTA15B5	1697831	285770	39	45	71	92	141	142	103	97	71	50	1	39	6	26	21	49
72	RTA16B2	1698078	290029	30	39	77	99	128	138	108	99	61	39	10	30	9	38	22	29
73	RTA21B7	1698141	290054	NO	24	NO	NO	NO	138	#######	114	#######	#######	#######	#######	#######	#######	#######	#######
74	RTA24B10	1698002	290577	NO	48	NO	NO	NO	137	#######	89	#######	#######	#######	#######	#######	#######	#######	#######
75	RTA25B1	1697730	290290	23	36	53	81	112	139	116	103	86	58	27	23	13	17	28	31
76	RTA26B12	1697754	290098	35	50	88	NO	NO	143	108	93	55	#######	#######	35	15	38	#######	#######
77	RTA28B14	1698066	290469	26	48	84	NO	NO	143	117	95	59	#######	#######	26	22	36	#######	#######
78	RTA29B15	1698176	290220	28	30	88	NO	NO	143	115	113	55	#######	#######	28	2	58	#######	#######
79	RTB26B1	1694673	299795	60	112	125	NO	177	136	76	24	11	#######	-41	60	52	13	#######	#######
80	RTB27B2	1689326	293918	46	75	82	89	109	162	116	87	80	73	53	46	29	7	7	20

(continue)

No.	well number	UTMN	UTME	bp	bo	bn	bm	a	elevation (m.)	mean sea level elevation					thickness (m.)				
									msl.	BP	BO	BN	BM	A	BQ	BP	BO	BN	BM
81	RTB34B9	1692468	299770	34	36	129	132	153	144	110	108	15	12	-9	34	2	93	3	21

Appendix II Analytical data of groundwater quality of the member BM

No.	Well Number	UTMN	UTME	Dept	Level	pH	conductivity uS/cm	Fe	Mn	Cl	NO3	F	TDS	TH	Analyzed date
1	DP260B1	1695916	294374	142	3	7.2	7870	6	0.32	2400	0.1	0.1	4350	460	09/01/41
2	DP261B2	1692725	294059	146	3	7.3	260	0.58	0.12	43	1.8	0.1	143	96	09/01/41
3	DP264B5	1689432	296510	97	2	7.6	150	6.4	0.07	8.4	0	0.1	82	56	12/14/41
4	RTB34B9	1692468	299770	150	3	6.5	365	1.9	0.11	34	0	0.1	214	160	11/10/41
5	MG1474B47	1700721	286803	121.5	2	8	11000	4.5	0.29	3500	0	0.1	6100	660	12/14/41
6	JJ1326B13	1694300	305600	93	2	6.5	17300	4.1	0.4	5500	0	0	9260	990	12/09/41
7	DP269B10	1688432	296028	110	2	6.4	437	13	0.19	48	1.6	0.2	286	230	11/11/41
8	DP275B16	1689719	306257	105	2	8.1	553	0.08	0.31	58	0	0.1	316	220	12/14/41
9	DQ289B8	1694652	298575	108	2	7.6	242	0.42	0.01	26	0.8	0.1	123	82	12/09/41
10	JJ1314B1	1694302	298641	108	2	7	193	1.8	0.19	13	2.2	0.1137	137	84	10/12/41
11	L1734B2	1691873	295852	136	2	7.2	266	0.54	0.69	37	2	0.1	161	97	09/01/41
12	L1736B4	1691849	303057	104	2	7.6	295	0.36	0.18	16	0	0.1	175	110	09/01/41
13	L1738B6	1691786	303010	108.5	2	6.3	377	7.6	0.14	40	0.2	0.2	237	170	11/11/41
14	L1740B8	1691877	302678	100	2	7	315	0.72	0.36	11	0.1	0.1	159	120	12/09/41
15	L1741B9	1691957	302811	111	2	6.9	416	4.4	0.33	44	0	0.1	219	140	12/09/41
16	L1744B12	1694271	300449	120	2	6.9	381	0.94	0.42	33	0	0.1	228	150	11/10/41
17	ML1490B8	1693635	298906	100	2	6.6	171	3	0.17	14	0	0.1	111	74	11/10/41
18	ML1491B9	1693709	298792	104	2	7	158	4	0.72	16	2.2	0.1	105	70	10/12/41
19	ML1492B10	1693200	302700	108	2	8	367	5.2	0.13	38	0	0.1	223	81	12/14/41
20	RTA33B19	1690344	298821	112	2	7.2	515	1.3	0.16	50	0	0.1	283	220	12/14/41
21	RTB27B2	1689326	293918	120	2	7.1	417	0.48	0.05	54	0.3	0.1	238	160	09/01/41
22	RTB28B3	1692310	304829	120	2	7.2	533	1.3	0.05	31	1.2	0.2	333	210	10/12/41
23	RTB32B7	1689855	298603	114	2	6.5	416	1.2	0.33	50	0.4	0.1	244	190	10/10/41
24	RTB33B8	1690344	298821	115	2	6.4	346	1.3	0.05	47	1.2	0.1	193	140	10/10/41
25	RTB35B10	1692173	299525	142	2	6.6	457	2.3	0.16	66	3.2	0.1	268	180	11/10/41
26	RTB38B13	1692483	304727	150	2	7.8	451	1.3	0.33	23	0	0.1	238	130	12/14/41
27	RTB39B14	1692438	304727	108	2	8	343	0.86	0.06	26	0	0.1	207	110	12/14/41

(continue)

No.	Well Number	UTMN	UTME	Dept	Level	pH	conductivity uS/cm	Fe	Mn	Cl	NO3	F	TDS	TH	Analyzed date
28	U1875B2	1693255	297592	108	2	6.4	188	1.5	0.13	15	0	0.1	118	84	09/09/41
29	U1880B7	1694918	294763	120	2	7.1	253	2.2	0.14	24	1.3	0.1	168	130	10/12/41
30	Y1879B1	1695594	296151	138	2	7.2	154	2.4	0.015	14	1.2	0.1	112	78	10/12/41
31	Y1886B8	1690605	306032	102	2	7.3	425	1.5	0.1	35	0.1	0.1	220	140	12/09/41

Appendix III **Analytical data of groundwater quality of the member BO**

No. no	Well Number	UTMN	UTME	TDS	Dept	Level	pH	conductivity uS/cm	Fe	Mn	Cl	NO3	F	TH	Analyzed date
1	AA1726B73	1696132	294984	92	88	2	7.3	140	11	0.11	13	0.1	0.1	50	
2	B2058B1	1695899	295045	95	86	2	6.4	137	2	0.09	13	0	0.1	60	09/09/41
3	B2060B3	1694523	298990	143	94	2	7	223	6.7	0.21	14	1.3	0.1	94	10/12/41
4	B2061B4	1694542	298896	137	94	2	7.4	176	2.2	0.18	17	1.3	0.1	84	10/12/41
5	B2063B6	1697830	295849	78	86	2	7.4	112	1.5	0.1	13	1.3	0.1	52	10/12/41
6	B2064B7	1695561	294870	70	86	2	7	124	1.8	0.21	11	0.1	0.1	53	12/09/41
7	B2069B12	1689830	298814	290	53	2	7.2	557	5.2	0.61	53	0.2	0.2	170	12/09/41
8	CC1673B4	1698830	288589	100	65	2	7.3	166	1.1	0.11	16	0	0.1	64	11/10/41
9	CC1674B5	1698811	288470	92	65	2	7.4	135	0.76	0.16	11	0.4	0.1	38	10/12/41
10	CC1676B7	1697001	287053	97	85	2	6.8	159	1.9	0.12	30	0	0.1	65	11/10/41
11	CC1677B8	1696420	288335	100	72	2	7.9	181	0.96	0.06	38	0	0.1	65	12/14/41
12	CC1678B9	1696474	288822	106	72	2	7.9	196	1.8	0.21	39	0	0.1	68	12/14/41
13	CC1679B10	1696464	288125	115	72	2	7.9	191	1.2	0.2	38	0	0.1	73	12/14/41
14	CC1680B11	1698870	285119	98	72	2	7.1	154	0.9	0.05	18	0	0.1	52	10/10/41
15	CC1682B13	1697386	291744	83	90	2	7.6	157	1	0.06	24	0	0.1	50	12/14/41
16	DP268B9	1689350	298012	204	93	2	6.4	318	1	0.06	47	3.6	0.1	150	11/11/41
17	DP270B11	1689240	298556	165	65	2	6.5	301	0.36	0.18	42	6	0.1	120	11/10/41
18	DP271B12	1689404	297320	187	98	2	6	349	4.3	0.17	46	3.6	0.1	140	11/10/41
19	DP273B14	1687474	305520	281	60	2	6.5	475	0.7	0.01	72	2.2	0.1	210	11/10/41
20	DP274B15	1687616	305528	299	95	2	7.3	556	0.96	0	58	0.1	0.1	210	12/09/41
21	DQ283B2	1695922	294992	92	84	2	7.3	129	0.82	0.17	12	0.1	0.1	50	09/01/41
22	DQ285B4	1697966	297017	75	84	2	6.3	115	0.96	0.05	14	0.1	0.1	48	11/11/41
23	DQ287B6	1694676	298628	169	96	2	7	257	4.4	0.15	16	2.2	0.1	92	10/12/41
24	DQ288B7	1694652	298575	110	96	2	6.3	153	4	0.45	10	0	0.1	70	11/11/41
25	DQ292B11	1692700	296900	87	80	2	6.9	190	3.8	0.09	32	0.9	0	62	12/09/41
26	JJ1315B2	1694223	298790	112	96	2	6.4	155	0.62	0.12	100	0	0.1	65	11/11/41
27	JJ1316B3	1694517	298849	102	93	2	6.4	144	0.62	0.08	10	0	0.1	60	11/11/41
28	JJ1317B4	1694460	298809	329	86	2	6.3	533	0.02	0.04	80	16	0.2	230	11/11/41
29	JJ1318B5	1694340	298849	106	90	2	6.4	150	1.3	0.16	12	0	0.1	54	11/11/41

(cotinue)

No. bo	Well Number	UTMN	UTME	TDS	Dept	Level	pH	conductivity uS/cm	Fe	Mn	Cl	NO3	F	TH	Analyzed date
30	JJ1319B6	1694464	298453	108	96	2	6.3	160	3	0.21	10	0	0.1	73	11/11/41
31	JJ1320B7	1694945	301909	304	96	2	7.3	526	5.1	0.45	97	0	0.1	88	11/10/41
32	JJ1321B8	1694685	301954	275	85.5	2	7.5	490	1.6	0.11	110	0	0.1	58	11/10/41
33	JJ1322B9	1694777	301757	263	88	2	7.4	446	1.1	0.04	61	0	0.2	86	11/10/41
34	JJ1323B10	1694496	301563	155	85	2	7.6	246	1	0.15	17	0	0.1	88	11/10/41
35	JJ1327B14	1694300	305600	295	33	2	6.8	655	0.84	0.84	170	1	0	57	12/09/41
36	L1733B1	1688024	293007	258	87	2	7.2	386	4.7	0.05	33	88	0.1	140	09/01/41
37	L1735B3	1697163	292826	783	92	2	7.5	1160	0.84	0.83	99	0.1	0.1	370	09/01/41
38	L1742B10	1695766	296600	95	95	2	6.3	142	0.6	0.04	11	0	0.1	51	11/11/41
39	L1743B11	1695590	296522	90	96	2	6.5	126	1.5	0.16	11	0	0.1	47	11/11/41
40	L1747B15	1686047	303168	332	48	2	6.4	549	0.88	0.15	64	12	0.1	260	10/10/41
41	L1748B16	1688024	293007	258	56	2	6.5	432	0.6	0.02	59	7.9	0.1	200	10/10/41
42	MG1461B34	1690656	288862	295	72	2	6.8	607	1.3	0.08	110	0.5	0.1	240	09/09/41
43	MG1467B40	1697773	285872	91	87	2	7.6	140	2.5	0.1	9.6	3.1	0.1	51	10/12/41
44	MG1469B42	1697504	290771	81	90	2	6.7	140	1.4	0.19	24	0	0.1	45	11/10/41
45	MG1472B45	1697746	290431	75	72	2	7.1	127	2.1	0.19	18	0	0.1	42	11/10/41
46	ML1486B4	1694448	298810	107	96	2	7.1	167	1.4	0.12	9.6	0	0.1	61	09/09/41
47	ML1487B5	1694544	298571	105	90	2	7.4	143	1.4	0.13	10	1.4	0.1	62	10/12/41
48	ML1488B6	1694122	298502	118	85	2	7	147	2.2	0.29	10	2.2	0.1	75	10/12/41
49	ML1489B7	1694675	298572	87	85	2	6.9	166	2.3	0.18	6.8	0.1	0	53	12/09/41
50	MK1506B1	1694881	290717	120	62	2	7.6	234	7.8	0.11	42	0.8	0.1	74	09/01/41
51	MK1507B2	1694765	290532	176	63	2	7.5	321	0.52	0.13	69	0.6	0.1	120	09/01/41
52	MK1509B4	1693463	290284	145	89	2	7.5	250	3	0.22	65	0.4	0.1	100	09/04/41
53	MK1510B5	1695081	290886	103	73	2	7.6	147	0.88	0.04	12	0.4	0.1	54	09/05/41
54	MK1511B6	1694882	290840	162	70	2	6.9	273	0.66	0.22	79	1.4	0.1	110	09/09/41
55	MK1512B7	1694713	291114	129	81	2	7.4	274	2.2	0.2	64	0	0.1	82	12/14/41
56	MK1513B8	1694621	290232	160	77	2	7.5	344	2.8	0.11	80	2.9	0.1	99	12/14/41
57	MK1514B19	1693929	290745	100	81	2	8	166	2.5	0.13	40	0	0.1	53	12/14/41

(cotinue)

No. bo	Well Number	UTMN	UTME	TDS	Dept	Level	pH	conductivity uS/cm	Fe	Mn	Cl	NO3	F	TH	Analyzed date
58	MK1515B10	1697644	290846	81	81	2	7	127	0.98	0.06	24	0	0.1	42	11/10/41
59	MY856B33	1697808	285920	105	85	2	7.7	158	1.6	0.06	16	3.1	0.1	60	10/12/41
60	MY857B34	1697788	285913	83	85	2	6.5	141	6.4	0.4	14	0	0.1	54	10/10/41
61	MY858B35	1697916	285881	93	85	2	6.6	151	1.1	0.09	17	0	0.1	57	10/10/41
62	MY859B36	1697829	285873	87	85	2	7.6	140	1.9	0.1	8.8	3.1	0.1	50	10/12/41
63	MY860B37	1697756	285877	88	81	2	7	127	3	0.08	14	2.5	0.1	68	10/12/41
64	MY861B38	1697820	285859	90	85	2	7.2	132	1.2	0.09	13	1.4	0.1	64	10/12/41
65	MY864B41	1698137	286208	86	89	2	6.9	136	1.4	0.07	14	0	0.1	54	10/10/41
66	MY865B42	1698090	286079	85	89	2	7.4	155	1.7	0.06	16	0	0.1	50	12/14/41
67	MY867B44	1697849	285867	147	85	2	6.4	256	0.9	0.14	17	0	0.1	120	10/10/41
68	MZ1016B2	1698097	290001	100	66	2	6.7	145	9.1	0.19	12	0	0.1	54	09/09/41
69	MZ1019B5	1691854	289250	189	90	2	6.8	366	0.66	0.17	82	3.4	0.1	130	09/09/41
70	MZ1020B6	1691705	289271	227	90	2	7.1	380	0.94	0.08	88	3.7	0.1	160	10/12/41
71	MZ1021B7	1690862	289157	225	75	2	7.1	361	2	0.12	72	5.9	0.1	140	10/12/41
72	MZ1022B8	1697551	291259	165	75	2	6.3	269	1	0.18	59	0	0.1	58	11/11/41
73	MZ1026B12	1698268	287425	95	78	2	6.3	147	1.2	0.05	20	0	0.1	67	11/11/41
74	RTA16B2	1698078	290029	84	72	2	7.2	130	4.1	0.1	17	0	0.1	31	09/01/41
75	RTA21B7	1698141	290054	85	86	2	6.2	133	1.1	0.04	20	0	0.1	42	09/09/41
76	RTA24B10	1698002	290577	81	89	2	6.5	230	15	0.19	16	0	0.1	44	11/11/41
77	RTA25B1	1697730	290290	90	79.2	2	7.2	130	2.4	0.11	29	0.3	0.1	43	10/12/41
78	RTA26B12	1697754	290098	75	86	2	7	114	1.7	0.09	19	0.1	0.1	36	09/11/41
79	RTA28B14	1698066	290469	79	73	2	6.7	128	1.2	0.08	19	0	0.1	44	09/12/41
80	RTA29B15	1698176	290220	140	85	2	6.6	230	1.3	0.08	26	0	0.1	98	09/13/41
81	TS318B18	1695741	296440	107	90	2	7.5	164	1.2	0.04	14	0.1	0.1	44	09/01/41
82	TS319B19	1695678	296489	117	98	2	7.4	179	1.5	0.09	13	0.1	0.3	55	09/01/41
83	TS320B20	1695657	296586	104	90	2	7.3	157	7.9	0.09	11	0.1	0.1	63	09/01/41
84	U1876B3	1695008	294774	117	90	2	7.4	180	2.7	0.17	8.8	1.4	0.1	90	10/12/41
85	U1877B4	1695646	295996	144	96	2	7	232	1	0.48	31	1.3	0.1	70	10/12/41

(cotinue)

No. bo	Well Number	UTMN	UTME	TDS	Dept	Level	pH	conductivity uS/cm	Fe	Mn	Cl	NO3	F	TH	Analyzed date
86	U1883B10	1694916	294667	98	96	2	6.2	147	2.4	0.16	15	0	0.1	63	11/11/41
87	U1884B11	1695229	295861	78	96	2	7.8	151	0.58	0.23	19	0	0.1	56	12/14/41
88	Y1882B4	1695319	296273	83	90	2	6.9	158	1.4	0.4	8	0	0.1	50	12/09/41
89	Y1883B5	1694041	301390	103	90	2	7.4	166	5.3	0.41	14	0	0.1	67	11/10/41
90	Y1884B6	1693534	301553	126	90	2	7.8	238	0.98	0.11	8	0	0.1	88	12/14/41
91	Y1885B7	1693515	301935	126	90	2	6.9	231	1.9	0.28	8	0.2	0.1	76	12/09/41
92	Z1911B2	1695948	295019	130	80	2	7.2	226	0.8	0.32	14	0.1	0.1	100	09/01/41
93	Z1912B3	1696066	295029	101	84.5	2	7.4	138	4.9	0.19	20	1.2	0.1	69	10/12/41
94	Z1913B4	1690091	295047	92	84.5	2	7.3	127	1.3	0.07	15	1.4	0.1	68	10/12/41
95	Z1914B5	1695877	295428	85	98	2	7	125	4.8	0.1	11	2.5	0.1	55	10/12/41
96	Z1915B6	1696202	294204	105	82	2	6.2	168	1.7	0.08	20	0	0.1	70	11/11/41
97	Z1916B7	1696232	294158	102	68	2	6.3	144	5.3	0.45	24	0	0.1	60	11/11/41
98	Z1917B8	1695962	294546	117	85	2	6.3	187	1	0.07	37	0	0.1	84	11/11/41

Appendix IV Analytical data of pumping test of the member BM

No.	Well Number	UTMN	UTME	depth	diameter	SWL	PL	DD	Q	time (hr.)	setting	casing	elevation	perforation		mean sea level (m.)	
														from	to	SWL	PLE
1	DP260B1	1695916	294374	142	150	0	29.58	29.58	11.18	12	60.5	40	138	126	138	138	108.42
2	DP264B5	1689432	296510	97	150	0	30.83	30.83	18.8	7	49.5	14	160	84	93	160	129.17
3	DP269B10	1688432	296028	110	150	6.14	46.89	40.75	11.02	9	48	14	167	97	106	160.86	120.11
4	DQ289B8	1694652	298575	108	150	0	14.89	14.89	8.72	7	24		136	95	104	136	121.11
5	L1734B132	1691873	295852	136	150	0	60	60	3.67	7	60	40	154	124	130	154	94
6	L1736B4	1691849	303057	104	150	0	34.54	34.54	5.04	8	43.5	39	138	94	100	138	103.46
7	L1738B6	1691786	303010	108.5	150	0	60.4	60.4	1.53	7	63.5	40	138	95	104	138	77.6
8	ML1490B8	1693635	298906	100	150	0	16.7	16.7	10.57	7	21	45	142	93	96	142	125.3
9	ML1491B9	1693709	298792	94	150	0	9.76	9.76	10.86	7	42	52	142	91	100	142	132.24
10	ML1492B10	1693200	302700	107	150	0	12.41	12.41	10.29	7	43	48	133	95	104	133	120.59
11	RTA33B19	1690344	298821	112	150	5.41	5.41	12.38	11.49	7	21	8	151	101	110	145.59	145.59
12	RTB27B2	1689326	293918	120	150	0	9.69	9.69	25.51	10	19.5	45	170	102	108	170	160.31
13	RTB34B9	1692468	299770	150	150	0	19.9	19.9	9.01	7	43.5	45	145	125	134	145	125.1
14	RTB38B13	1692483	304727	150	100	0	64.7	64.7	2.88	7	69	20	129	144	147	129	64.3
15	MG1474B47	1700721	286803	121.5	100	0.78	21.57	20.79	7.2	7	27	62	137	96	99	136.22	115.43

Appendix V Analytical data of pumping test of the member BO

No.	Well Number	UTMN	UTME	depth	diameter	SWL	PL	DD	Q	time (hr.)	setting	casing	elevation	perforation		mean sea level (m.)	
														from	to	SWL	PLE
1	AA1726B733	1696132	294984	86	150	0	29.67	29.67	21.3	10	60	35	141	62	74	141	111.33
2	B2058B1	1695899	295045	86	150	0	40.03	40.03	9.85	7	40.03	46.5	139	73	82	139	98.97
3	B2060B3	1694523	298990	94	150	0	31.23	31.23	10.57	7	46.5	27	136	76.5	90	136	104.77
4	B2061B4	1694542	298896	94	150	0	42.65	42.65	4.8	7	45	36	138	76	90	138	95.35
5	B2063B6	1697830	295849	86	150	0	20.66	20.66	11.83	10	30	13	133	70	82	133	112.34
6	B2064B7	1695561	294870	86	150	0	33.12	33.12	9.55	7	36	36	141	70	82	141	107.88
7	CC1673B4	1698830	288589	65	150	0.77	10.36	9.59	11.92	7	21	35	140	59	68	139.23	129.64
8	CC1674B5	1698811	288470	65	150	0	26.38	26.38	8.29	7	36	35	138	52	61	138	111.62
9	CC1676B7	1697001	287053	85	150	0	33.19	33.19	11.7	10	36	33	140	72	81	140	106.81
10	CC1677B8	1696420	288335	72	150	0	21.25	21.25	11.47	7	30	36	146	59	68	146	124.75
11	CC1678B9	1696474	288822	72	150	0	37.32	37.32	4.8	7	39	37	146	59	68	146	108.68
12	CC1679B10	1696464	288125	90	150	0	34.85	34.85	7.97	7	36	35	146	59	68	146	111.15
13	CC1680B11	1698870	285119	72	150	0	20.99	20.99	11.47	8	20.99	24	140	60	69	140	119.01
14	CC1682B13	1697386	291744	90	150	0	18.56	18.56	14.473	7	30	49	135	60	69	135	116.44
15	DP268B9	1689350	298012	93	150	0.4	15.79	15.39	15.45	9	27	9	160	80	89	159.6	144.21
16	DP270B11	1689240	298556	65	150	1.11	14.89	13.78	14.07	9	21	13.5	165	52	61	163.89	150.11
17	DP272B13	1691000	306300		150	0	14.8	14.8	9.01	7	30	41	131			131	116.2
18	DP273B14	1687474	305520	60	150	0	9.29	9.29	15.45	7	34.5	35	132	47	56	132	122.71
19	DP274B15	1687616	305528	95	150	0	14.79	14.79	11.27	7	24	16	132	56	62	132	117.21
20	DP275B16	1689719	306257	104	150	0	38.86	38.86	5.04	7	45	14	132	92	101	132	93.14
21	DQ283B2	1695922	294992	84	150	0	17.67	17.67	15.05	8	21	36	138	72	81	138	120.33
22	DQ285B4	1697966	297017	84	150	0	27.45	27.45	10.21	7	33	29	132	66.5	80	132	104.55
23	DQ287B6	1694676	298628	96	150	0	28.28	28.28	9.92	7	43.5	38	136	81.5	92	136	107.72
24	DQ288B7	1694652	298575	96	150	0	28.49	28.49	6.08	7	43.5	34	136	83	92	136	107.51

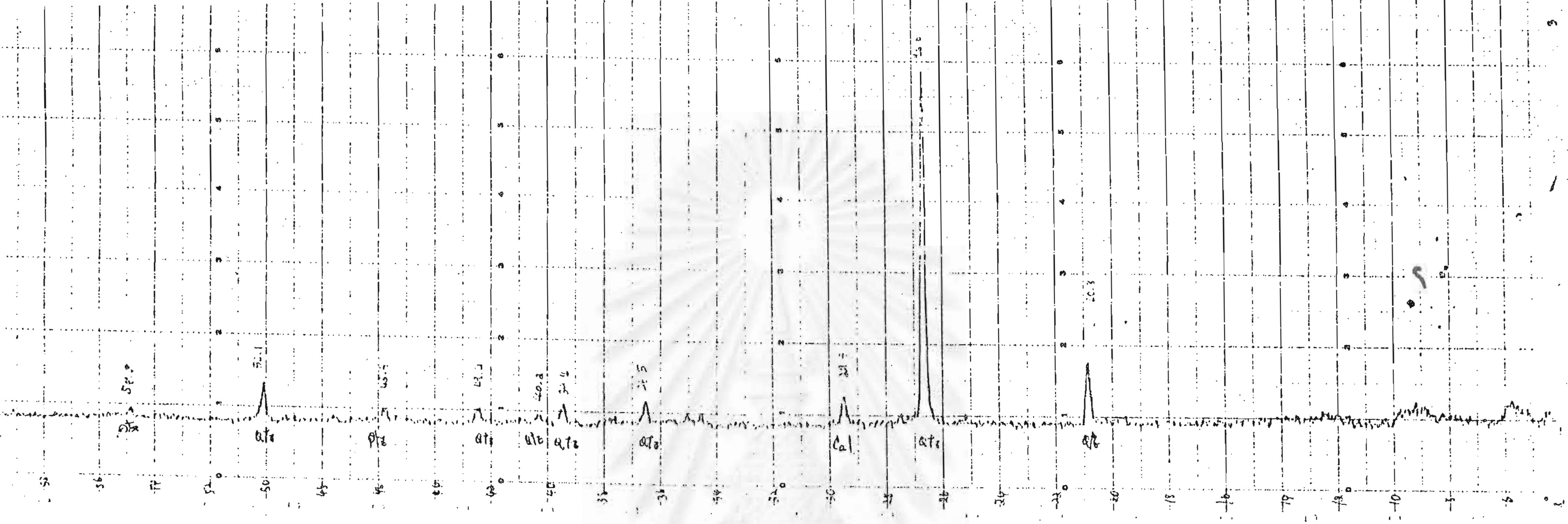
(continue)

No.	Well Number	UTMN	UTME	depth	diameter	SWL	PL	DD	Q	time (hr.)	setting	casing	elevation	perforation		mean sea level (m.)	
														from	to	SWL	PLE
25	DQ292B11	1692700	296900	79	100	0	27.33	27.33	4	7	42	30	150	83	92	150	122.67
26	L1733B1	1688024	293007	88	150	5.95	8.33	2.33	22.52	10	55.5	40	177	58	87	171.05	168.67
27	L1735B3	1697163	292826	92	150	0	11.52	11.52	12.73	10	30	41	133	82	88	133	121.48
28	L1742B10	1695766	296600	95	150	0	13.57	13.57	12.73	7	24	37	136	73	91	136	122.43
29	MG1461B34	1690656	288862	93	?	7.12	48.02	40.9	3.43	10	60	24	146	62	68	138.88	97.98
30	MG1467B40	1697773	285872	87	150	0	29.51	29.51	19.21	10	46.5	50	142	74	83	142	112.49
31	MG1469B42	1697504	290771	90	150	0	21.22	21.22	12.73	10	36	33	142	77	86	142	120.78
32	MG1472B45	1697746	290431	72	150	0.4	39.98	39.58	5.04	9	44	12	138	59	68	137.6	98.02
33	MK1506B1	1694881	290717	62	150	0	31.53	31.53	19.63	7	46.5	40	143	52	58	143	111.47
34	MK1507B2	1694765	290532	63	150	0	37.12	37.12	17.97	7	49.5	28	142	60	69	142	104.88
35	MK1508B3	1693362	290738	90	150	0	29.62	29.62	17.54	10	46.5	33	150	80	86	150	120.38
36	MK1509B4	1693463	290284	77	150	3.63	27.42	23.79	8.12	10	30	30	155	76	85	151.37	127.58
37	MK1510B5	1695081	290886	70	150	0	6.25	6.25	13.71	8	21	30	155	60	69	155	148.75
38	MK1511B6	1694882	290840	70	150	0	12.27	12.27	12.64	8	24	49	147	60	66	147	134.73
39	MK1512B7	1694713	291114	76	150	0	22.83	22.83	14.43	7	30	42	147	68	77	147	124.17
40	MK1513B8	1694621	290232	73.75	150	0	10.53	10.53	15.45	7	23	32	148	64	73	148	137.47
41	MK1514B19	1693929	290745	81	150	0	12.09	12.09	13.52	7	33	35	148	68	77	148	135.91
42	MK1515B10	1697644	290846	81	150	0	21.75	21.75	11.74	7	24	40	149	68	77	149	127.25
43	ML1486B4	1694448	298810	96	150	0	15.43	15.43	13.05	7	36	42	138	75	84	138	122.57
44	ML1487B5	1694544	298571	90	150	0	42.31	42.31	7.47	7	45	34	138	72.5	86	138	95.69
45	ML1488B6	1694122	298502	85	150	0	21.18	21.18	7.3	8	36	39	139	72	81	139	117.82
46	ML1489B7	1694675	298572	85	150	0	17.41	17.41	6	7	51	54	138	72	81	138	120.59
47	MY856B33	1697808	285920	85	150	0	33.87	33.87	19.21	10	46.5	47	138	72	81	138	104.13

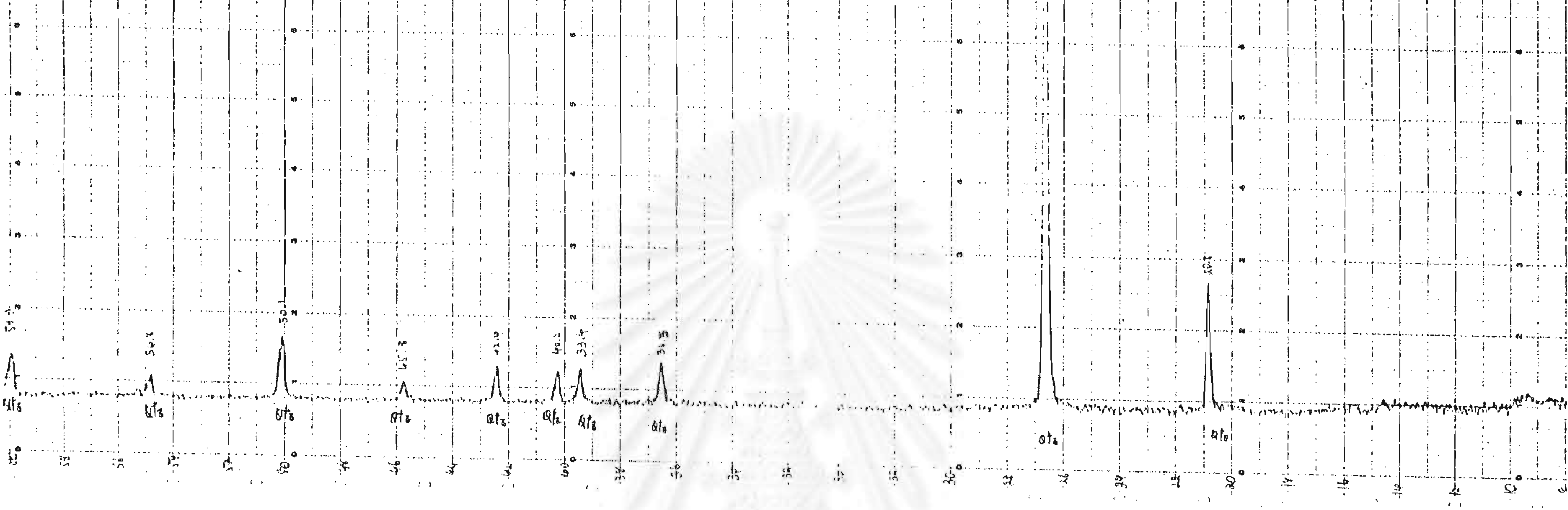
(continue)

No.	Well Number	UTMN	UTME	depth	diameter	SWL	PL	DD	Q	time (hr.)	setting	casing	elevation	perforation		mean sea level (m.)	
														from	to	SWL	PLE
48	MY857B34	1697788	285913	84	150	0	28.23	28.23	15.28	7	33	50	141	66	77	141	112.77
49	MY858B35	1697916	285881	84	150	0	24.3	24.3	16.34	7	33	59	140	72	81	140	115.7
50	MY859B36	1697829	285873	85	150	0	28.39	28.39	19.21	7	46.5	64	140	72	81	140	111.61
51	MY860B37	1697756	285877	83	150	0	27.31	27.31	19.21	7	?	56	140	64	73	140	112.69
52	MY861B38	1697820	285859	80	150	0	25.06	25.06	11.7	7	36	59	140	72	81	140	114.94
53	MY864B41	1698137	286208	83.63	150	0	7.2	7.2	7.49	7	30	54	139	76	85	139	131.8
54	MY865B42	1698090	286079	87	150	0	10.18	10.18	14.69	7	21	61	139	76	85	139	128.82
55	MY867B44	1697849	285867	85	150	0	11.19	11.19	14.43	10	30	37	140	72	81	140	128.81
56	MZ1016B2	1698097	290001	65	150	3.15	34.87	31.72	11.02	8	37.5	12	142	56	62	138.85	107.13
57	MZ1019B5	1691854	289250	90	150	11.7	29.81	18.12	12.85	7	39	38	168	77	86	156.3	138.19
58	MZ1020B6	1691705	289271	90	150	10.2	26.78	16.58	14.25	7	45	20	168	77	86	157.8	141.22
59	MZ1021B7	1690862	289157	75	150	1.26	16.43	15.17	14.78	7	30	42	168	62	71	166.74	151.57
60	MZ1022B8	1697551	291259	75	150	0	15.21	15.21	12.64	10	30	44	170	62	75	170	154.79
61	MZ1026B12	1698268	287425	63	150	0	20.47	20.47	11.47	7	30	37	164	65	74	164	143.53
62	mz1028b14	1696600	288800	82.5	100	12.88	27.42	14.54	7.12	7	36	55	143	93	96	130.12	115.58
63	RTA16B2	1698078	290029	144	6?	1.33	55.21	53.88	3.53	10	60	27	138	72	78	136.67	82.79
64	RTA21B7	1698141	290054	79.33	150	1.25	31.42	30.17	16.64	72	46.5	22	138	76	82	136.75	106.58
65	RTA24B10	1698002	290577	87	150	0.05	17.07	17.02	14.95	7	30	23	138	80	83	137.95	120.93
66	RTA25B1	1697730	290290	80	150	0	48.95	48.95	5.04	10	54	43	137	73	76	137	88.05
67	RTA26B12	1697754	290098	86	150	0	23.98	23.98	10.32	7	30	35	139	80	83	139	115.02
68	RTA28B14	1698066	290469	72	150	0	38.15	38.15	8.12	10	48	25	138	61	70	138	99.85
69	RTA29B15	1698176	290220	85	150	0	13.08	13.08	13.71	10	30	47	138	72	81	138	124.92
70	RTA31B17	1697315	291598	90	150	0	8.94	8.94	12.12	7	21	73	138	85	88	138	129.06

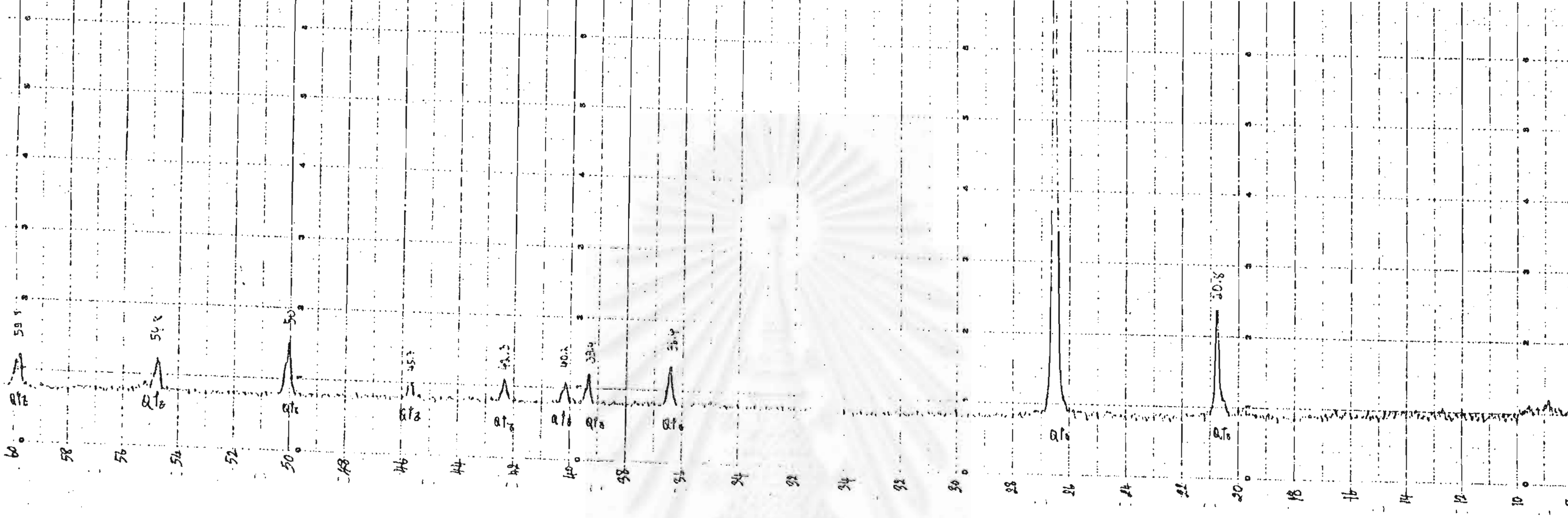
Appendix V **X-ray diffractograph of some representative of the samples of the major zone in lithostratigraphic sequence of the study area**



X-ray diffractograph of formation A that consisted of quartz and gypsum.



X-ray diffractograph of member BN that consisted of quartz.



X-ray diffractograph of member BP that consisted of quartz.

Appendix VI **X-ray diffractograph of some representative of the samples of the major zone in lithostratigraphic sequence of the study area**

Appendix VII Well reference number and cuttings information

WELL LOG

Groundwater Division, Department of Mineral Resources

PROJECT : น้ำบาดาลเพื่อพัฒนาทุ่งกุลาร้องไห้

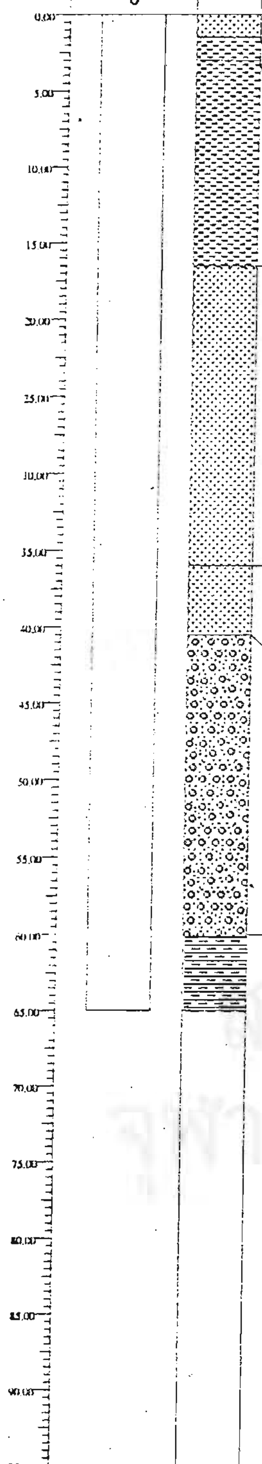
WELL NO : *DP270B11* LocationX : *298556* LocationY : *1689240* MAP SHEET : *5639 IV*

LOCATION : *บ้านหนองการะโก หมู่ที่7 ต.แคนดง,กิ่ง อ.แคนดง,จ.บุรีรัมย์.*

WATER LEVEL : *Null* DEPTH : *Null* DIAMETER : *6"* LOG BY : *Thassanee Netasna*

DRILL METHOD : *Direct Rot*DRILL BY : *DMR* DATE : *23/5/42*

WELL DESIGN	SYM	DESCRIPTION
—6—		



SAND:pinkish brown, fine sand to medum sand, subrounded to rounded, very well sorted, composed of quartz.

CLAY:yellow, sndy, limonitic, plsstic, compacted.

CLAY:yellow, gray mottled, high plasticity.

SAND:pale brown, fine sand to medium sand, subrounded to rounded, very well sorted, composed of quartz, chert.

SAND:orangish brown, medium sand to coarse sand, very well sorted, composed of quartz, chert.

SAND&GRAVEL:various colors. very coarse sand to fine gravel, subrounded, well sorted to very well sorted, composed of quartz, chert, jassper.

CLAYSTONE:purplish brown, high plasticity.

REMARK: บ่อเกษตร

WELL SYMBOL :

WELL LOG

Groundwater Division, Department of Mineral Resources

PROJECT : น้ำบาดาลเพื่อพัฒนาทุ่งกุลาร้องไห้

WELL NO : MK1506B1 LocationX : 290717 LocationY : 1694881 MAP SHEET : 5639 IV

LOCATION : โรงเรียนบ้านหนองขุนพรหม,บ้านหนองขุนพรหม หมู่ที่ 17 ต.ปะเคียบ,อ.คูเมือง,จ.บุรีรัมย์.

WATER LEVEL : Null DEPTH : 147 DIAMETER : 6" LOG BY : Thassanee Netusna

DRILL METHOD : Direct RotaDRILL BY : DMR DATE : 11/6/42

Depth	WELL DESIGN	SYM	DESCRIPTION
0.00	6		SAND:brown, fine sand to medium sand, subrounded, very well sorted, compose of quartz.
			CLAY:yellowish browm and brownish white, sandy, plastic.
11.00			SAND:light brown, medium sand to coarse sand, subangular, very well sorted, composed of quartz.
22.00			CLAY:light brown, high plasticity.
33.00			SAND:light brown, fine sand to medium sand, sunrounded, very well sorted, composed of quartz.
44.00 – 66.00			SAND:light gray, medium sand to very coarse sand, subangular to subrounded, composed of quartz, chert.
77.00			SAND & GRAVEL:coarse sand to fine gravel, subangular, well sorted, consists of 50% sand, 50% gravel, compose of quartz, chert.
88.00			CLAY:gray, sandy, plastic.
			SAND:gray, aphanitic to fine sand, subrounded, composed of quartz, chert.
99.00			CLAY:gray, sandy, plastic.
110.00 – 143.00			SAND:gray, medium sand to very coarse sand, subangular to subrounded, compose of quartz, chert.
143.00 – 209.00			CLAYSTONE:purplish brown.

Depth scale: 0.00, 11.00, 22.00, 33.00, 44.00, 55.00, 66.00, 77.00, 88.00, 99.00, 110.00, 121.00, 132.00, 143.00, 154.00, 165.00, 176.00, 187.00, 198.00, 209.00

REMARK: AR

WELL SYMBOL :

WELL LOG

Groundwater Division, Department of Mineral Resources.

PROJECT : น้ำบาดาลเพื่อพัฒนาทุ่งกุลาร้องไห้

WELL NO : *DP260B1* LocationX : *295023* LocationY : *1695921* MAP SHEET : *5639 IV*

LOCATION : *วัดสระบัว.บ้านสระบัว หมู่ที่ 1 ต. สระบัว,กิ่ง อ.แคนดง,จ.บุรีรัมย์.*

WATER LEVEL : *Null* DEPTH : *164* DIAMETER : *6"* LOG BY : *Sunthorn Punjasuthuros*

DRILL METHOD : *Direct Rot*DRILL BY : *DMR* DATE : *23/5/42*

WELL DESIGN	SYM	DESCRIPTION
—6—		
		CLAY:brown and pale brown, siilty, limonitic, plastic.
		SAND:pale brown, gravelly, medium sand to very coarse sand, subangular to subrounded, moderately sorted, composed of quartz, chert with sandstone fragments.
		SAND & CLAY:pale grayish brown, limonitic, slightly gravelly, fine sand to medium sand, composed of quartz, chert.
		SAND:pale grayish brown, clayey, gravelly, medium sand to very coarse sand, subrounded, composed of quartz, chert.
		CLAY:brownish yellow, limonitic, high plasticity.
		SAND:browish gray, clayey, carbonaceous, coarse sand to very coarse sand, subangular to subrounded, very well sorted, composed of quartz, chert.
		CLAY:gray, sandy, high plasticity.
		SAND:brownish gray, clayey, carbonaceous, coarse sand to very coarse sand, subangular to subrounded, very well sorted, composed of quartz, chert.
		CLAY:gray, silty, high plasticity.
		SAND:brownish gray, gravelly, medium sand to very coarse sand, subangular to subrounded, well sorted, composed of quartz, chert.
		CLAY:gray, sandy, high plasticity.
		SAND:brownish gray, gravelly, medium sand to very coarse sand, subangular to sunrounded, well sorted, composed of quartz, chert.
		CLAY:gray, sandy, carbonaceous.
		SAND:brownish gray, gravelly, medium sand to very coarse sand, subangular to subrounded, well sorted, composed of quartz, chert.
		SAND & GRAVEL:gray, fine sand to fine gravel, well sorted to moderately sorted, composed of quartz, chert, siltstone, fining upward.
		SAND:brown and grayish brown, fine sand, very well sorted, composed of quartz, loose.
		MUDSTONE:reddish brown, composed of andesite presented in places, moderately weathered to highly weathered.

Depth scale: 0.00, 12.00, 24.00, 36.00, 48.00, 60.00, 72.00, 84.00, 96.00, 108.00, 120.00, 132.00, 144.00, 156.00, 168.00, 180.00, 192.00, 204.00, 216.00, 228.00

REMARK: AR

WELL SYMBOL :

WELL LOG

Groundwater Division, Department of Mineral Resources

PROJECT : น้ำบาดาลเพื่อพัฒนาทุ่งกุลาร้องไห้

WELL NO : AA1727B734 LocationX : 298174 LocationY : 1694211 MAP SHEET : 5639 IV

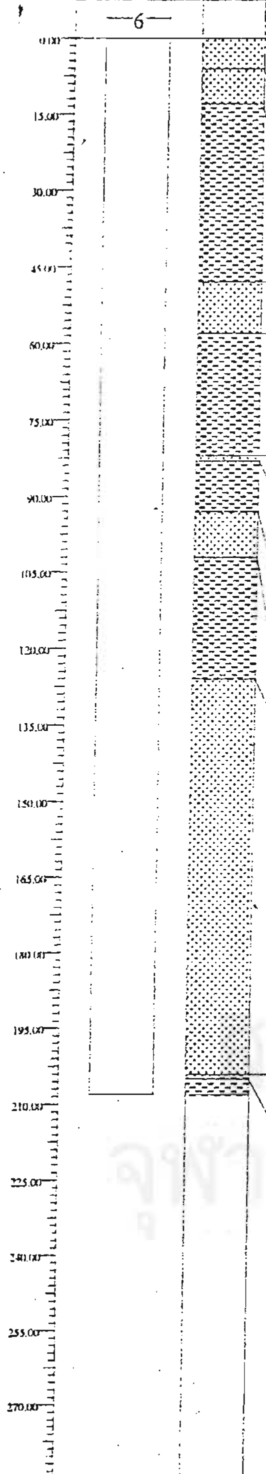
LOCATION : วัดราษฎร์สามัคคี,บ้านหนองซองแมว หมู่ที่ 6 ต.แคนดง,กิ่ง อ.แคนดง,จ.บุรีรัมย์.

WATER LEVEL : Null DEPTH : 208 DIAMETER : 6" LOG BY : Thassanee Netasna

DRILL METHOD : Direct RotaDRILL BY : DMR DATE : 20/5/42

WELL DESIGN	SYM	DESCRIPTION

—6—



SAND:brown and orangish brown, fine sand, subrounded to rounded, very well sorted, composed of quartz, plastic, loose.

SAND:brownish yellow, fine sand, subrounded to rounded, very well sorted, composed of quartz, loose.

CLAY :yellow and grayish yellow, sandy, lateritic, composed of laterite fragments, high plasticity.

SAND:grayish brown, medium sand to coarse sand, subrounded, very well sorted, composed of quartz.

CLAY:gray and dark gray, sandy, limonitic,composed of carbonaceous matter presented in place, high plasticity.

SAND:grayish brown, medium sand to coarse sand, subrounded, very well sorted,composed of quartz.

CLAY:gray and dark gray, sandy, limonitic, composed of carbonaceous matter presented in place, high plasticity.

SAND:pale yellowish brown, fine sand to medium sand, rounded, very well sorted, composed of quartz, coal presented at the lower parts, loose.

CLAY:pale yellowish brown, sandy, plastic.

SAND:medium sand to coarse sand, subrounded to rounded, very well sorted, composed of quartz, chert with gravel presented at the lower parts, size increased with depth.

CLAY:brown, limonitic, plastic.

CLAY:reddish brown, composed of gypsum, anhydrite, slightly plastic.

REMARK: บ่อชำรุด

WELL SYMBOL :

WELL LOG

Groundwater Division, Department of Mineral Resources

PROJECT : น้ำบาดาลเพื่อพัฒนาทุ่งกุลาร้องไห้

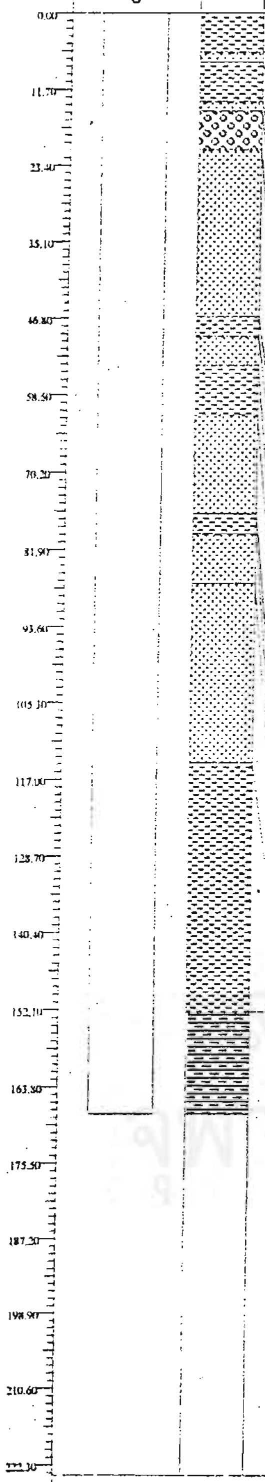
WELL NO : *ML1492B10* LocationX : *Null* LocationY : *Null* MAP SHEET : *5639 IV*

LOCATION : *บ้านดงพลอง หมู่ที่ 1 ต.ดงพลอง,กิ่ง อ.แคนดง,จ.บุรีรัมย์.*

WATER LEVEL : *Null* DEPTH : *168* DIAMETER : *6"* LOG BY : *Null*

DRILL METHOD : *Direct Rot*DRILL BY : *DMR* DATE : *12/6/42*

WELL DESIGN	SYM	DESCRIPTION
6		



CLAY:dark brown, sandy, limonitic, plastic.

SAND:yellowish brown, medium sand to very coarse sand, subangular to subrounded, very well sorted, composed of quartz, feldspars, chert.

CLAY:brown, sandy, slightly plastic.

SAND:pale yellow, medium sand to coarse sand, subangular to subrounded, well sorted, composed of quartz, feldspars, chert.

GRAVEL:pale yellow, very coarse sand to very fine gravel, subangular to subrounded, well sorted, composed of quartz, feldspars, chert.

SAND:pale yellowish brown, medium sand to very coarse sand, subangular to subrounded, well sorted, composed of quartz, chert.

CLAY:brownish gray, sandy, plastic.

SAND:brownish gray, medium sand to very coarse sand, subrounded, well sorted, composed of quartz, chert, feldspars.

CLAY:light gray, subrounded, moderately sorted.

SAND:light greenish brown, medium sand to coarse sand, subrounded, well sorted, composed of quartz, chert, feldspars.

CLAY:light gray, sandy, plastic.

SAND:light gray, clayey, gravelly, very fine sand to coarse sand, composed of quartz, chert.

SAND:light gray and gray, medium sand to coarse sand, subrounded, well sorted to very well sorted, composed of quartz, chert.

CLAY:gray and dark gray, sandy, high plasticity, compacted.

CLAYSTONE:dark reddish brown.

Null

WELL SYMBOL :

WELL LOG

Groundwater Division, Department of Mineral Resources

PROJECT : น้ำบาดาลเพื่อพัฒนาทุ่งกุลาร้องไห้

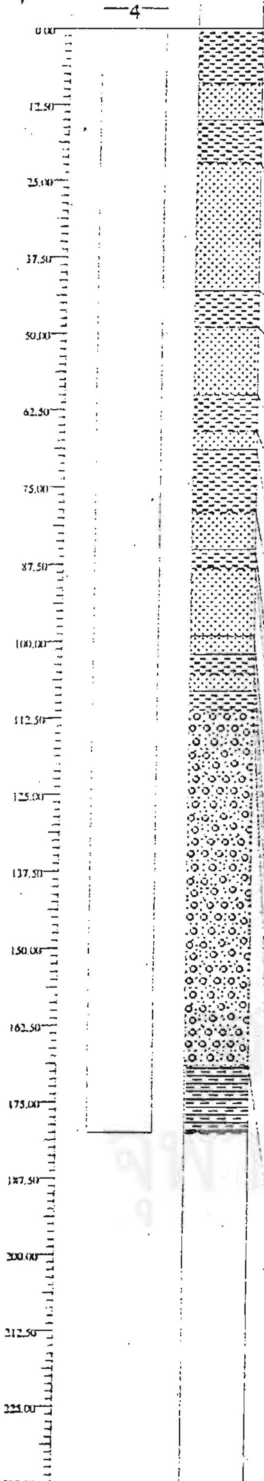
WELL NO : *ML1494B12* LocationX : *Null* LocationY : *Null* MAP SHEET : *5639 IV*

LOCATION : *บ้านหนองแสง หมู่ที่ 5 ต.แคนดง.กิ่ง อ.แคนดง.จ.บุรีรัมย์.*

WATER LEVEL : *Null* DEPTH : *180* DIAMETER : *4"* LOG BY : *Mahippong Worakul*

DRILL METHOD : *Direct Rot*DRILL BY : *DMR* DATE : *12/6/42*

WELL DESIGN	SYM	DESCRIPTION
—4—		



CLAY:yellowish brown, yellow mottled, high plasticity.

SAND:yellowish brown, slightly clayey, medium sand to coarse sand, subangular to subrounded, well sorted, composed of quartz, feldspars, chert with jasper.

CLAY:grayish brown, slightly sandy, plastic.

SAND:very light grayish brown, coarse sand to very coasre sand, subangular to subrounded, moderately sorted to well sorted, composed of quartz, chert with feldspars fragments.

CLAY:grayish brown, sandy, limonitic, slightly plastic to plastic.

SAND:very light brownish gray, medium sand to very coarse sand, subangular to subrounded, moderately sorted, composed of quartz, chert, feldspars.

CLAY:brownish gray, slightly sandy, slightly plastic to plastic.

SAND:grayish brown, coarse sand to very coarse sand, subangular to subrounded, well sorted, composed of quartz, chert with feldspars.

CLAY:dark gray, gray mottled, slightly sandy, plastic.

SAND:light brownish gray, slightly gravelly, coarse sand to very coarse sand, subangular to subrounded, well sorted, composed of quartz, chert, feldspars.

CLAY:dark gray, slightly gravelly, slightly plastic.

SAND:gray, slightly gravelly, medium sand to very coarse sand, subangular to subrounded, moderately sorted to well sorted, composed of quartz, chert.

SAND:brownish gray, medium sand to very coarse sand,subangular to subrounded, composed of quartz, chert.

CLAY:gray, sandy, slightly plastic.

SAND:light grayish brown, slightly clayey, medium sand to very coarse sand, subangular to subrounded, moderately sorted, composed of quartz, chert.

CLAY:dark gray, gravelly, nonplastic.

GRAVEL & SAND:light gray, slightly clayey, coarse sand to very fine gravel, angular to subrounded, moderately sorted to well sorted, consists of 70% gravel, 30% sand, composed of quartz, chert.

CLAYSTONE:reddish brown, moderately weathered.

REMARK: บ่อสังเกตการณ์

WELL SYMBOL :

WELL LOG

Groundwater Division, Department of Mineral Resources.

PROJECT : *น้ำบาดาลเพื่อพัฒนาทุ่งกุลาร้องไห้*

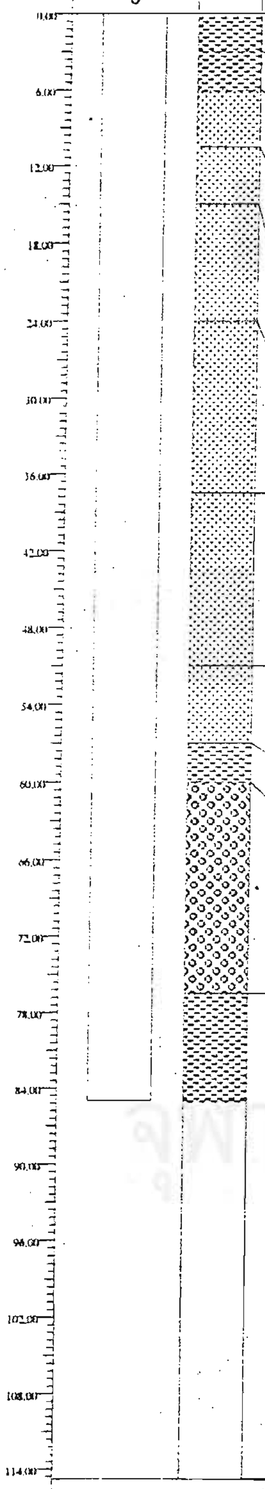
WELL NO : *MY857B34* LocationX : *285913* LocationY : *1697788* MAP SHEET : *5639 IV*

LOCATION : *บ้านโนนเพกา หมู่ที่ 7 ต.บ้านแพ,อ.คูเมือง,จ.บุรีรัมย์.*

WATER LEVEL : *Null* DEPTH : *85* DIAMETER : *6"* LOG BY : *Mahippong Worakul*

DRILL METHOD : *Direct Rot*DRILL BY : *DMR* DATE : *12/6/42*

WELL DESIGN	SYM	DESCRIPTION
—6—		



CLAY:yellowish brown, gray mottled, slightly silty, nonplastic.

CLAY:grayish brown, yellow mottled, slightly silty, slightly plastic.

SAND:light yellowish brown,medium sand, angular to subangular, very well sorted, composed of quartz, feldspars, rock fragments.

SAND:yellowish brown, clayey, fine sand to coarse sand, angular to subangular, moderately sorted, composed of quartz, feldspars, chert.

SAND:light brownish yellow, medium sand to coarse sand, angular to subrounded, well sorted, composed of quartz, feldspars,rock fragments.

SAND:pinkish brown and light brown, slightly clayey, medium sand to very coarse sand, subangular to subrounded, well sorted, composed of quartz, feldspars, chert with rock fragments.

SAND:light yellowish brown, medium sand to coarse sand, angular to subrounded, well sorted, composed of quartz, feldspars, chert.

SAND:light gray, gravelly, medium sand to very coarse sand, subangular to subrounded, well sorted, composed of quartz, feldspars, chert with jasper, rock fragments.

CLAY:gray, gravelly, nonplastic.

GRAVEL:gray and brownish gray, slightly clayey, very fine gravel, subangular to subrounded, well sorted, composed of quartz, chert, interbedded with shale fragments.

CLAY:dark gray, sandy, carbonaceous, nonoplastic.

REMARK: จุดจ่ายน้ำ

WELL SYMBOL :

WELL LOG

Groundwater Division, Department of Mineral Resources

PROJECT : น้ำบาดาลเพื่อพัฒนาทุ่งกุลาร้องไห้

WELL NO : *TS325B25* LocationX : *287281* LocationY : *1694778* MAP SHEET : *5639 IV*

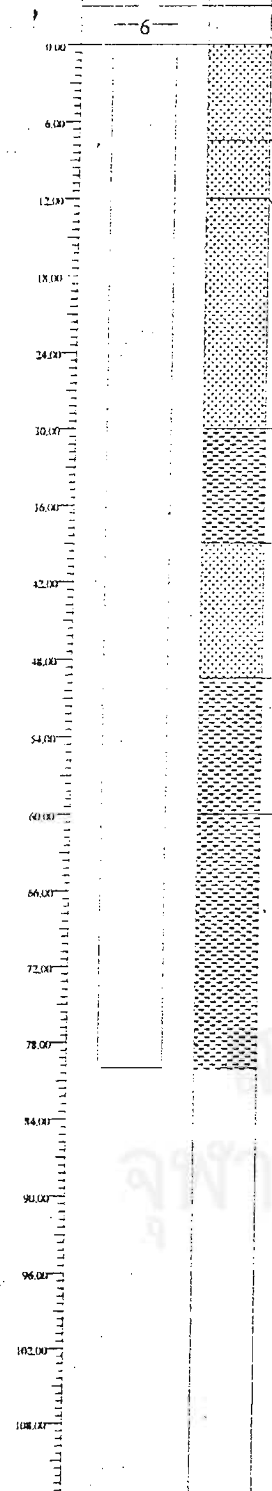
LOCATION : บ้านดงเค็ง หมู่ที่ 5 ต.หนองขมาร,อ.คูเมือง,จ.บุรีรัมย์.

WATER LEVEL : *Null* DEPTH : *80* DIAMETER : *6"* LOG BY : *Auchalee Nakplong*

DRILL METHOD : *Direct Rot*DRILL BY : *DMR* DATE : *13/6/42*

WELL DESIGN	SYM	DESCRIPTION

—6—



SAND:pinkish brown and reddish brown, silty, slightly clayey, fine sand to very coarse sand, subangular to subrounded, well sorted, composed of quartz, latterite.

SAND:yellowish brown and grayish yellow, highly with limonitic, hightly clayey, fine sand to very coarse sand, subangular to subrounded, moderately sorted.

SAND:pale gray and pinkish gray, silty, clayey, medium sand to very coarse sand, subangular to subrounded, well sorted, composed of quartz, chert, flint with laterite, limonite presented in places.

CLAY:yellowish gray and pinkish gray, sandy, limonite stained, composed of quartz, laterite, flint presented in places, high plasticity.

SAND:yellowish brow, highly clayey, clayey, fine sand to very coarse sand, subangular to subrounded, moderately sorted.

CLAY:yellowish gray and gray, sandy, limonie stained, high plasticity.

CLAY:brownish gray and gray, yellow mottled, highly carbonaceous, slightly, high plasticity.

REMARK: บ่อเกษตร

WELL SYMBOL :

WELL LOG

Groundwater Division, Department of Mineral Resources

PROJECT : น้ำบาดาลเพื่อพัฒนาทุ่งกุลาร้องไห้
WELL NO : MY856B33 LocationX : 285933 LocationY : 1697981 MAP SHEET : 5639 IV
LOCATION : บ้านโนนเหลา หมู่ที่7 ต.บ้านแพ,อ.คูเมือง,จ.บุรีรัมย์.
WATER LEVEL : Null DEPTH : 85.5 DIAMETER : 6" LOG BY : Mahippong Worakul
DRILL METHOD : Direct RotaDRILL BY : DMR DATE : 22/06/99

WELL DESIGN	SYM	DESCRIPTION
6		
		CLAY: light yellowish brown, slightly sandy, low plastic.
		SAND: pale brownish gray towhite, medium to coarse grained, moderately sorted, subangular to subrounded, composed maimly of quartz, some feldspar and rock fragment.
		CLAY: yellowish brown, slightly sandy, low plastic.
		SAND: light yellowish brown to light brown, medium to very coarse grained, moderately sorted, subangular to subrounded, composed domaintly of quartz, some feldspar and rock fragments.
		SAND: light gray, coarse to very coarse grained, moderatly sorted, angular to subrounded, composed of quartz, some feldspars, chert jasper, basalt and other kinds of rock fragments.
		CLAY: greenish gray, some sand inparts, low plastic.
		SAND: light gray, some gravel inparts, medium to very coarse grained, moderately sorted,angular to subrounded, composed mostly of quartz, some feldspars, chert, jasper, basalt and fragments.
		CLAY: gray, some sand inparts, non to low plastic.

0.00 6.00 12.00 18.00 24.00 30.00 36.00 42.00 48.00 54.00 60.00 66.00 72.00 78.00 84.00 90.00 96.00 102.00 108.00 114.00

REMARK: จุดจ่ายน้ำ

WELL SYMBOL :

WELL LOG

Groundwater Division, Department of Mineral Resources

PROJECT : น้ำบาดาลเพื่อพัฒนาทุ่งกุลาร้องไห้

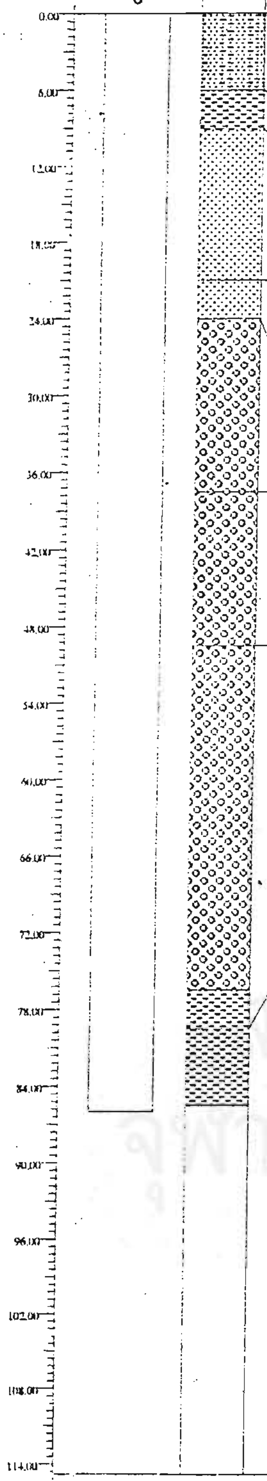
WELL NO : *RTA21B7* LocationX : *290054* LocationY : *1698141* MAP SHEET : *5639IV*

LOCATION : *วัดคงย่อ, บ้านคงย่อ หมู่ที่ 3 ต.ปะเคียบ.อ.คูเมือง.จ.บุรีรัมย์.*

WATER LEVEL : *Null* DEPTH : *85.5* DIAMETER : *6"* LOG BY : *Mahippong Worakul*

DRILL METHOD : *Direct Rou*DRILL BY : *DMR* DATE : *23/06/99*

WELL DESIGN	SYM	DESCRIPTION
—6—		



CLAYEY SAND: light brown,20-40%clayey, medium to coarse grained, poorly sooted, subangular to subrounded, composed mainly of quartz, some feldspars and iron-oxide coated sediments.

CLAY: light brown, slightly sandy and gravelly, low plastic.

SAND: light brown, slightly clayey, medium to very coarse grained, moderately sorted, subangular to suarounded, composed dominantly of quartz. some feldspar, chert and iron- oxide coated sediments.

SAND: light brownish gray, coarse to very coarse grained, moderately to well sorted, subangular to subrounded, composed mainly of quartz,some feldspar, chert and rock fragments.

GRAVEL: grayish brown, slightly clayey and sandy, 2-4 mm. in size, moderately sorted, subangular to subrounded, composed of quartz, feldspar, chert, basalt and rock fragments.

CLAYEY GRAVEL: light grayish brown, 20-40%clayey, gravel same as24 -39.5

GRAVEL: lightly brownish gray, some sand in parts, 2-3mm. in size,moderately to well sorted, subangular tosubrounded, composed dominainly of quartz,some feldspar, chert, basalt and other rock fragments.

CLAY: brownish gray, slightly gravelly, low plastic.

REMARK: จุดจ่ายน้ำ

WELL SYMBOL :

WELL LOG

Groundwater Division, Department of Mineral Resources

PROJECT : น้ำบาดาลเพื่อพัฒนาทุ่งกุลาร้องไห้

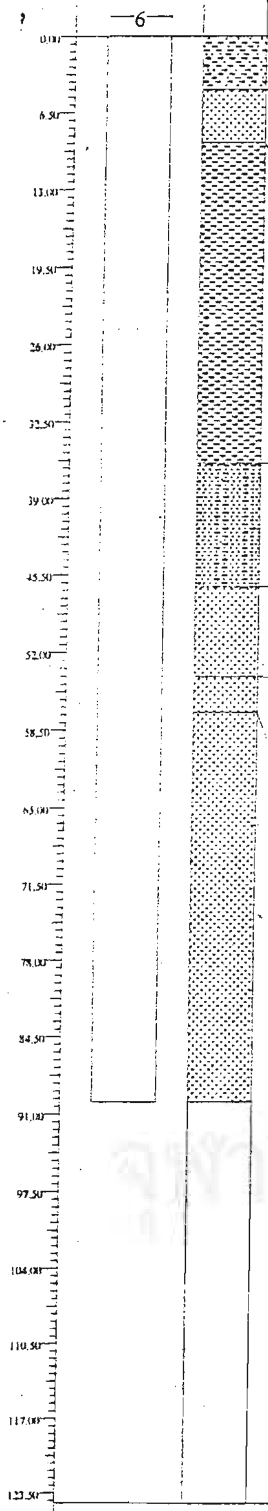
WELL NO : *MK1509B4* LocationX : *290284* LocationY : *1693463* MAP SHEET : *5639 IV*

LOCATION : *ที่สาธารณะบ้านหนองขุนพรหม,บ้านหนองขุนพรหม หมู่ที่ 17 ต.ปะเคียบ,อ.คูเมือง,จ.บุรีรัมย์.*

WATER LEVEL : *Null* DEPTH : *90* DIAMETER : *6"* LOG BY : *Mahippong Worakul*

DRILL METHOD : *Direct Rot*DRILL BY : *DMR* DATE : *24/06/99*

WELL DESIGN	SYM	DESCRIPTION
—6—		



SANDY CLAY: yellowish brown, 20-40% sandy, non plastic.

SAND: pale brown, slightly clayey, very fine to medium grained, modratelty sorted, subangular, composed mostly of quartz, some feldspar.

CLAY: light brown to light grayish brown, slightly silty, limonitic and reddish brown mottled, moderately to high plastic.

CLAYEY SAND: light greenish gray, 20-30% clayey, fine to medium grained, moderately sorted, subangular, composed dominantly of quartz, some feldspar and rock fragments.

SAND: light greenish gray, fine sand to medium grained, moderayely to well sorted, subangular to subrounded, composed of majority of quartz, some feldspar.

SAND: light brown, some gravel in parts, medium to very coarse grained, poorly sorted, subangular to subrounded, composed mainly of quartz, some feldspar, chert and iron-oxide coated material.

SAND: light greenish gray to light gray, medium to coasre grained, moderately to well sorted, subangular to subrounded, composed dominantly of quartz, some feldspar, chert and iron-oxide coated particles, some peat fragment at the last 6 m.

REMARK: บ่อเกษตร

WELL SYMBOL :

WELL LOG

Groundwater Division, Department of Mineral Resources

PROJECT : *น้ำบาดาลเพื่อพัฒนาทุ่งกุลาร้องไห้*

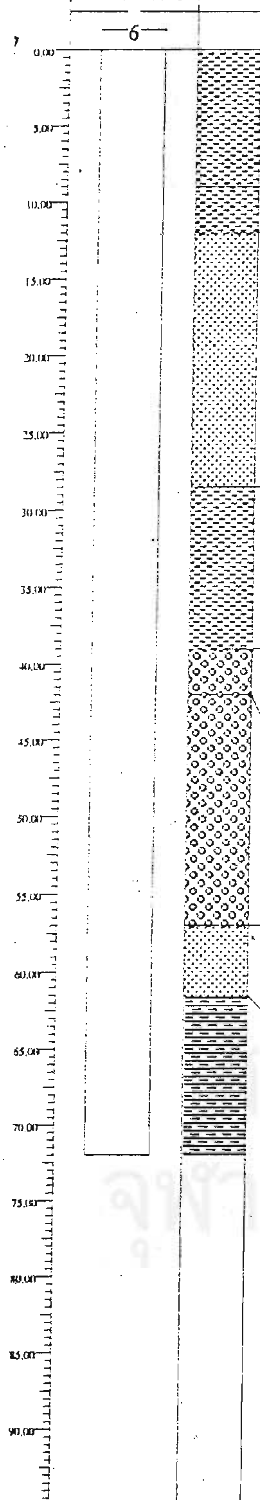
WELL NO : *MG1462B35* LocationX : *287333* LocationY : *1691905* MAP SHEET : *5639 IV*

LOCATION : *บ้านโคกสว่าง หมู่ที่ 6 ต. ปะเคียบ.อ. คูเมือง.จ. บุรีรัมย์.*

WATER LEVEL : *Null* DEPTH : *72* DIAMETER : *6"* LOG BY : *Mahippong Worakul*

DRILL METHOD : *Direct Rot*DRILL BY : *DMR* DATE : *24/06/99*

WELL DESIGN	SYM	DESCRIPTION
—6—		



CLAY: light yellowish brown to light brown, some silt and sand in parts, limonitic and reddish brown mottled, moderately plastic.

CLAY: reddish brown, slightly sandy, pale yellow mottled, low to moderately plastic.

SAND: yellowish brown, fine to coarse grained, moderately sorted, subangular to subrounded, composed mainly of quartz, some feldspar, rock fragments and iron-oxide coated sediments.

CLAY: reddish brown, some sand in parts, light gray mottled, moderately plastic.

GRAVEL: pale brown, 2-2 mm. in size, poorly sorted, subangular to subrounded, composed dominantly of quartz, some feldspars, chert,basalt androck fragments.

GRAVEL: light,2-3 mm.in size, modrately sorted; subangular to subrounded, composed abundantly of quartz, some feldspar, chert, basalt and rock frangment.

SAND: light greenish gray, medium to very coarse grained, moderatelt sorted, subangular to subrounded, composed mostly of quartz, some feldspar, chert and rock fragments.

CLAYSTONE: reddish brown, semiconsolidated.

REMARK: AR

WELL SYMBOL :

VITA

Mr. Bhuwadol Wanthanachaisaeng was born in Amphoe Muang, Changwat Chon Buri, in May 18, 1974. He received the degree of B. Sc. in Geology from Chulalongkorn University in 1996 and began graduate work there in 1997.